Technical Report 1725
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Periscope Detection System Test Report

K. E. Jennings

EXECUTIVE SUMMARY

The Navy has a mission needs statement (MNS 22 April 92) for a periscope detection capability. The Surface Ship Periscope Detection Radar (SSPDR) project was initiated to determine if a commercial off-the-shelf (COTS) radar track processor system could meet the requirements of the MNS. A COTS system built by CEA Ltd. of Australia was identified as a candidate for testing and evaluation. The initial testing (Phase 1) of the CEA system was funded by the Naval Science Assistance Program (NSAP) and performed at the Pacific Missile Range Facility (PMRF). The purpose of the first test was to determine the capability of the CEA radar track processor to detect submarines operating at periscope depth, as currently configured for use in the Navy's Mobile Inshore Underwater Warfare–System Upgrade (MIUW–SU) Program. The system demonstrated an excellent capability in the detection of periscopes to the theoretical limits of the installation.

Phase 1 tests were performed from 30 September to 13 December 1994. Personnel from Naval Command, Control and Ocean Surveillance Center (NCCOSC) Research, Development, Test and Evaluation Division (NRaD), Codes 372 and 755, and CEA Ltd. participated in the testing.

The CEA system tested was comprised of a modified Furuno 10-kW radar antenna, Mobile Inshore Radar Surveillance System (MIRSS) radar track processing equipment, and a Hewlett Packard (HP) workstation.

The radar location was at the Vandal launch site at PMRF, a coastal site overlooking a submarine operating range. The site dictated the antenna height to be 111.5 feet (higher than a typical shipboard installation of 50 to 100 feet). However, the added height provided no range improvement because the system is limited by the noise and clutter.

The Phase 1 tests were "piggybacked" on another periscope detection project, APS 137, which paid for the range and specified the submarine runs. The submarine executed hexagonal runs with various masts periodically exposed for specified amounts of time. There was only one run when the submarine was doing an "attack exposure" run on 6 December 1996. This "attack exposure" run was the most valuable data analyzed. The data were analyzed by playing back the recorded workstation data and logging when the Special Plots from the CEA Mirss Tracker (SPLOTS) were first detected and then lost. This formed the basis for the probability of detection and false alarm calculations.

The results showed detections in the range of 10,000 yards, matching well with the predicted range. The calculated probability of successfully classifying a mast exposure is 0.7, providing mast exposure exceed 15 sec. Two false alarms were recorded during the "attack exposure" run, however, these were due to land based reflections.

Follow-on funding has been obtained through the Foreign Comparative Test Program (sponsored by the Navy International Programs Office) to adapt the CEA system to shipboard use. Further testing is scheduled to be conducted in conjunction with RIMPAC exercises in May 1996.

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1. INTRODUCTION

The purpose of this test was to evaluate the CEA Mobile Inshore Radar Surveillance System (MIRSS) capability in detecting and classifying mast exposure opportunities at ranges out to the performance limit of the radar sensor used. The CEA MIRSS radar processing and sensor management system is designed for the automatic detection, tracking, and classification of surface, air, and exposed submarine mast targets.

2. EQUIPMENT UNDER TEST/CONFIGURATION AND CONDITIONS

2.1 HARDWARE CONFIGURATION

The equipment was designed and manufactured by CEA Technologies PTY Limited, and is composed of three prime functional units:

1. A Modified FURUNO FR100D 10-kW peak pulse power radar antenna and transmitter/receiver assembly.
2. The MIRSS radar processing enclosure (as used in the Mobile Inshore Underwater Warfare–System Upgrade (MIUW-SU) system) with a single workstation interface (including a commercial off-the-shelf (COTS) maintenance notebook PC).
3. A Hewlett Packard HP 712 workstation (COTS) (with CEA application software) that provided the platform for the CEA display, data recording/replay functions, and the mast classification algorithms.

The layout is shown in figures 1, 2, and 3.

The CEA MIRSS system provides two automatic detection and tracking paths, one for surface and air targets and the other for the special requirements of the (submarine) mast detection system. Some target types will produce only tracks of one type or another, and some will produce responses in both trackers. The detection and classification algorithms used in this test are required to attempt to categorize the targets belonging to the mast exposure category.

Both tracking systems were operated in parallel throughout the test period. Analyzed data from both sources and the classification process are supplied in the test results section of this report.

The submarine mast detection system classification process is primarily based on the time and motion constraints of submarine operations involving mast exposures. It provides lower probability of false alerts than the surface/air tracker along with a higher certainty of track declaration.

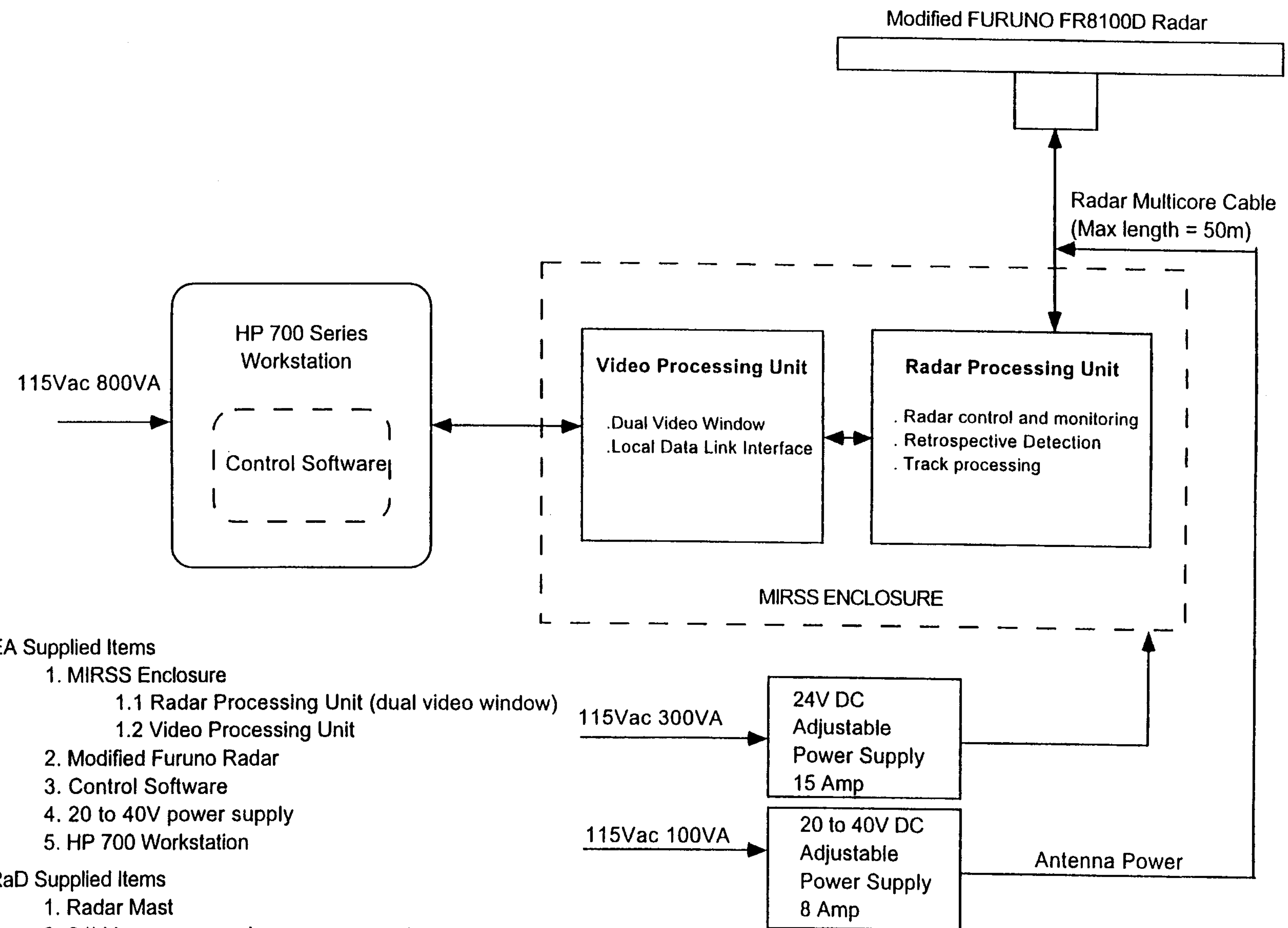
The mast detection functions are summarized in the processing flow diagram (figure 4). In this diagram, the multiple exposure algorithm shown as the last stages of the process is not yet present in the CEA-SCOPE software, and was not exercised in the test system. It can, however, be subsequently run using the recorded data from the test replayed into a fully configured software system to evaluate its effect on the false alert and classification process. This last stage process should reduce the false alert rate and will be provided to the operator as a confidence factor on basic stage two alerts.

2.2 SOFTWARE CONFIGURATION

2.2.1 Firmware Changes from the MIUW-SU Configuration

Firmware changes from the MIUW-SU firmware to the MIRSS system for this mast test configuration consisted of the following significant elements.

2.2.1.1 Special Plot Extraction Process. This is an algorithm that derives special plots (SPLOTS) that should normally be associated only with mast exposure type targets and other similarly small and slow-speed targets. The false alarm rate on these SPLOTS is approximately 5 to 10



CEA Supplied Items
1. MIRSS Enclosure
    1.1 Radar Processing Unit (dual video window)
    1.2 Video Processing Unit
2. Modified Furuno Radar
3. Control Software
4. 20 to 40V power supply
5. HP 700 Workstation

NRaD Supplied Items
1. Radar Mast
2. 24Vdc power supply

Figure 1. Periscope detection trials configuration.

RADAR CONTROL AND MONITORING FUNCTIONS

Provide operational controls and status for the radar and display processing system.

DISPLAY FUNCTIONS

Display
1. map
2. tracks
3. plots
4. special plots
5. operator controls

RECORDING AND REPLAY FUNCTIONS

Provide recording and replay facilities for
1. plots
2. special plots
3. tracks
4. detection alerts

Manage 24 hour recording files.

CLASSIFICATION FUNCTIONS

Examine special plots in relation to existing tracks and defined threat areas. Calculate the probability that any set of special plots is a probable periscope. Conduct the threshold detection based on the probability and previous history. Generate operator alerts.

Figure 2. Periscope detection software functions.

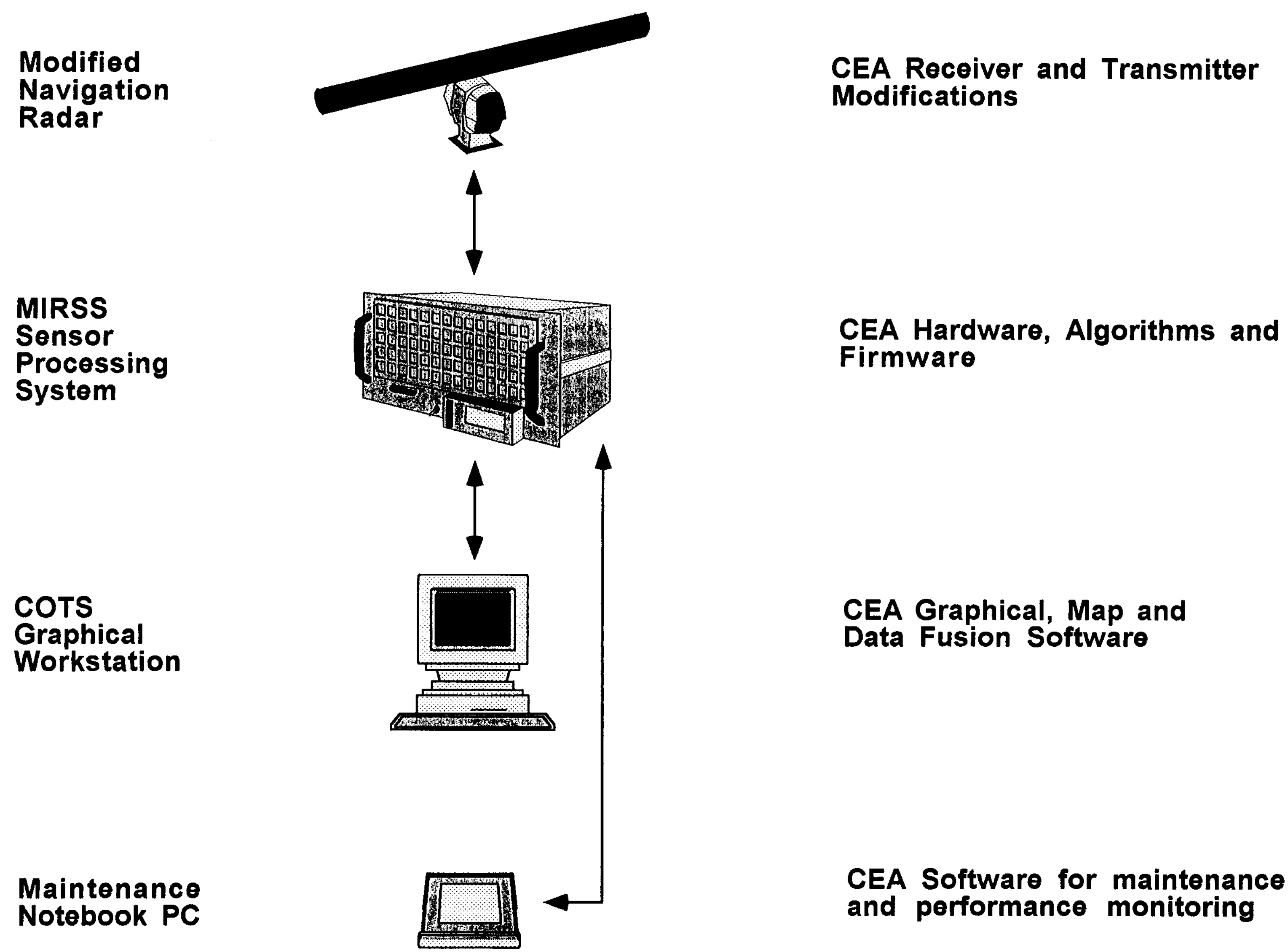


Figure 3. Periscope detection trials physical configuration.

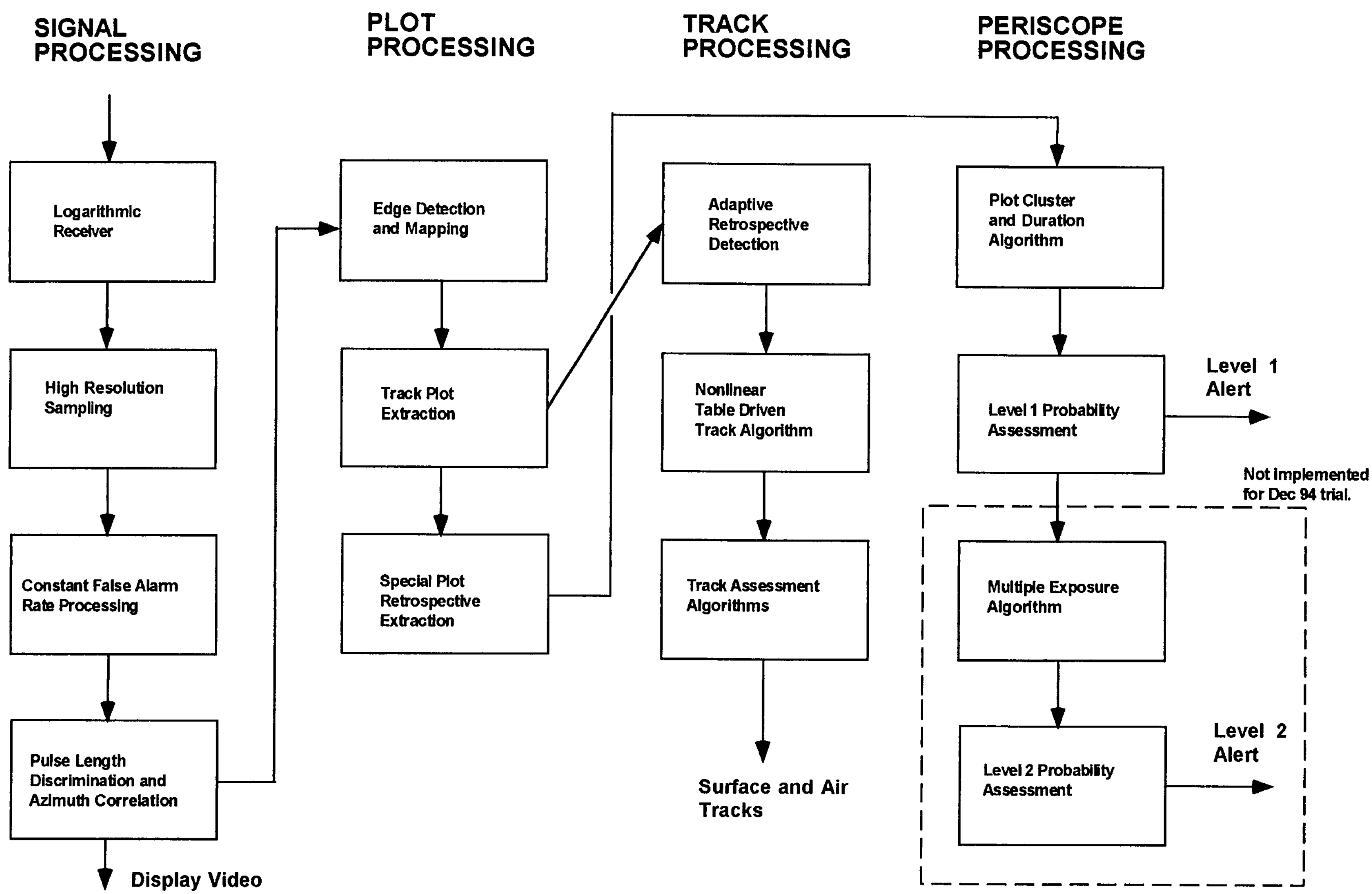


Figure 4. Signal processing sequence functional distribution.

per scan of the radar antenna. These SPLOTS are reported to the detection, tracking, and classification algorithms contained in the workstation .

2.2.1.2 Filter Detector Control. This is a new element of system control to manage the resources of the latest version of the filter detector card V235-1 used for this trial. This new version of the filter detector card has improved and expanded the Constant False Alarm Rate (CFAR), correlation, and signal processing functions relevant to the mast detection process.

2.2.2 System Control and Display Software

The version of system control and display software used for this test was a modified version of the CEA-RANGER software configured to provide the additional algorithms for the mast detection and classification process. This version of the software is called CEA-SCOPE. This software is a sensor control and management package with data fusion capability and an integrated dual window graphical display. It was developed for the surveillance of a military experimental and proof firing range. Many of the functions and modules of this software are also being incorporated into the MIUW-SU Graphic Data Fusion Software (GDFS) software package.

2.2.3 Software Detection and Classification Facilities

The software detection facilities provided for the test are embedded in the CEA-SCOPE software package hosted on the COTS (HP) workstation.

The functional distribution of the detection and classification algorithms is shown in figure 4. The test configuration did not include the last stage "multiple exposure algorithm" due to timing constraints for the test.

2.3 SITE CONFIGURATION

2.3.1 Location

The test site was located at the northern end of the Pacific Missile Range Facility (PMRF) on the launch site.

The coordinates of the antenna placement at the site were:

*Latitude: 22 degrees, 04 min, 17.0686 sec, north
*Longitude: 159 degrees, 46 min, 38.4528 sec, west
(*This position was determined from PMRF-supplied survey data).

The equipment was located in the launcher control room and the antenna was placed on the control room roof.

2.3.2 Antenna Height

The radar antenna was fixed at a larger than normal height of 34 m (111.5 ft) above mean sea level due to the constraints of sites and facilities. This height was determined from PMRF-supplied survey data. A typical ship-fitted height of 15 to 30 m (50 to 100 ft) would be expected for most systems of the type to be used for this function. The additional height used in this test does not provide an advantage for either range or sea clutter performance as the radar is performance-limited for detection of masts, not horizon-range-limited as shown in the performance prediction section of the report.

The additional height does, however, increase the incidence angle to the sea surface and, hence, the detrimental effect of sea clutter. Additionally, the typical shipboard configuration has the surface humidity duct significantly lower in height than the antenna height. The test configuration leaves the radar antenna above the duct and the target well within the duct. No significant advantage to the radar is provided by this test situation.

Placement of the antenna at a lower height, particularly near the upper bound of the typical humidity duct height (12 to 18 m), could actually provide some advantage to the detection of masts at slightly longer ranges and the discrimination of masts from the sea clutter environment at medium and short ranges.

2.3.3 System Alignment

System alignment was carried out by comparison of the radar video returns from the coastline and islands, and was retained throughout the test period. Although this alignment was not as accurate as desired, the comparison of the range-supplied track and the radar-system-derived track enabled the fixed calibration errors (both azimuth and range) to be removed from the results.

See appendix A for the analysis and reduction of the measurement error components, and the subsequent correction of data to allow direct comparison between range measured and radar derived data.

3. SCHEDULE

The following is a brief synopsis covering the activity of the trial team over the period covering 30 September to 14 December 1994 on the range at PMRF Kauai.

The CEA-leased equipment arrived on site over the period 30 September to 2 December 1994, and was installed and operational by 1600 on 2 December.

2 December 1994

Preliminary testing of the system commenced. During this activity, variability in the level of detection was experienced and investigated. A problem with the automatic receiver tuning system under some conditions of the Pulse Repetition Frequency (PRF) and the antenna rotation rate was diagnosed, and the constraints of operational parameters were identified. All subsequent data collected were acquired at a maximum antenna rotation rate of 30 rpm and radar average PRF of 1000 pps.

3 December 1994

Unable to collect significant data due to high power mode used by APS137.

4 December 1994

Significant data collected on approximately 60% of the day's runs. Unable to collect data on the remaining runs due to APS137 high-power mode. Some data were contaminated by the radar tuning problem.

5 December 1994

Trials canceled due to unserviceability of the target.

6 December 1994

Tactical runs were carried out during visit of Naval Science Assistance Program (NSAP) team.

7 December to 13 December 1994

Targets of opportunity were tracked to attempt to gain data for the continuing development of classification and detection algorithms.

14 December 1994

The equipment was packed and readied for shipment.

4. PROBLEMS AND LIMITATIONS

4.1 AUTOMATIC TUNING CONTROL PROBLEM

4.1.1 Description

After the equipment was set up on-site, a problem was diagnosed with the Automatic Tuning Control for the receiver, which precluded the use of PRFs higher than 1000 pps. This imposed a limitation on the effective antenna scan rate of less than 30 rpm in order to achieve adequate hits in a beam width.

This prevented operation of the equipment in its optimum configuration for mast detection, where the scan rate is 45 rpm and the PRF is 1800 pps. This problem was isolated to a temperature-related fault in the particular trial unit receiver circuits. It has not previously or subsequently been experienced on any other units.

4.1.2 Effect

The effect of this deficiency was to decrease the number of effective scans able to produce hits on the target during a short 20-second exposure (from 15 to 8) for the higher scan/PRF mode.

This single factor had a significant effect on the probability of detection and correct classification.

In addition, the same tuning problem produced some variability of system tune during the test runs and was estimated to have provided as much as 3 to 5 dB of degradation during some runs. The results were annotated when this effect was noticed.

4.1.3 Solution

The problem was the factory setup of the receiver automatic frequency control functions and can be overcome at the factory. The problem was not recognized before shipment of the equipment. There was a shortfall in a new test procedure and has since been rectified.

4.2 RECEIVE BLANKING FUNCTION

4.2.1 Description

The normal facility for receive blanking in which areas of land are removed from the radar processing data was unavailable.

This problem was a result of the introduction of the new Filter Detector PCB V236-1 that provides a range of new facilities for the effective reduction of clutter and discrimination of small targets. This was fixed in later releases of the printed circuit card.

4.2.2 Effect

The effect of this deficiency on the performance of the system was minimal, with much of the land-clutter area able to be removed through the use of a transmit blanking sector.

4.2.3 Solution

This deficiency was corrected in the next version of the V236-1 (currently in production but was unavailable for the test).

4.3 SITE LAYOUT AND REFLECTIONS

4.3.1 Description

The site layout for the trial was less than optimum, with poor visibility to the southwest and south, and high and variable reflection areas as a result of the two APS137 vans sited in that sector. These vans, when illuminated, provided a large area of clutter reflection over the southwest sector by producing back scatter from the cliff face to the east and northeast, which appears in the operational areas. In addition, the frequent opening of the door to the APS137 equipment van produced large flashes of clutter due to multipath from the cliffs.

Visibility to the north of the radar is severely limited by the large CCTV mount within 1 ft of the radar antenna on the roof of the launcher control room. On a bearing of 340 to 345 degrees, the radar had a decreased sensitivity due to a large lighting tower on the edge of the launch pad area. The site layout is shown in figure 5, with the seaward view from the test site.

4.3.2 Effect

The siting effects produced areas of both decreased sensitivity and severe interference caused by the abnormal reflections from the APS137 vans and the cliffs behind the site. The proximity to the large flat metallic surfaces of the APS137 van also introduced large transient flashes of clutter in the test measurement area whenever the van door was opened. This produced some false alerts on bearings between 135 and 270 degrees.

4.3.3 Solution

This effect was a result of the specific test and site constraints and was not typical of the siting constraints likely to be experienced even on complicated mast structures. The submarine was generally operating in the clear area between 275 and 310 degrees where the interference was less of a problem.

4.4 APS137 HIGH-POWER MODE

4.4.1 Description

Initial setup requirements for operation with the APS137 radar were cleared for 50-kW peak power from the APS137 and average power approaching 50 W.

The test conditions used by the APS137 group required operation of the system at a peak power level of 500 kW. This was deemed to present an unreasonable risk to the front end of the modified navigation radar when both radars were operating at the same antenna height and spaced by less than 26 m.

As a consequence, the modified FURUNO radar was secured with a waveguide shutter for considerable periods of time when the APS137 was operated in high-power mode. This limited the data collection in many runs.

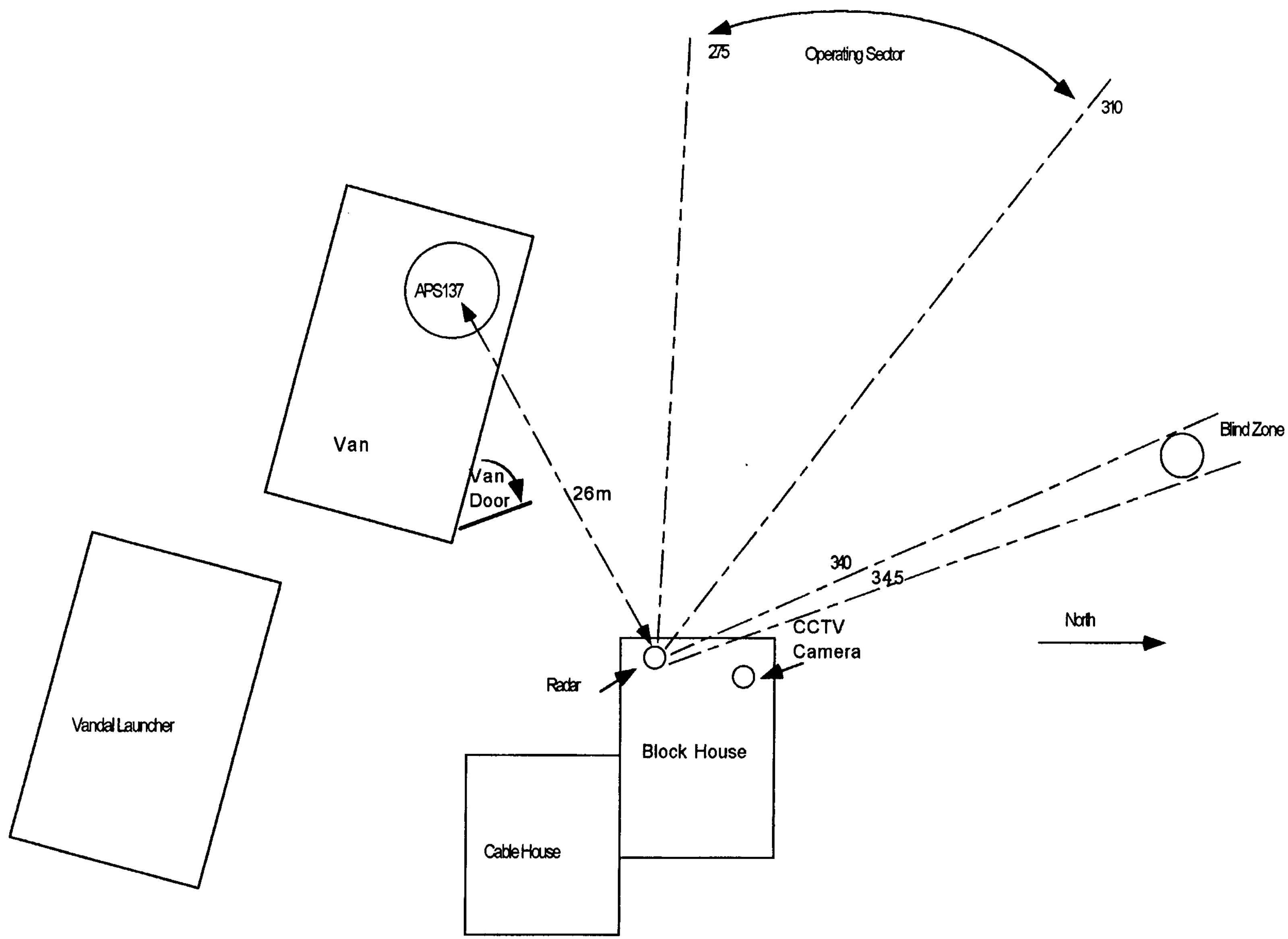


Figure 5. Test site layout.

Sea State 1 – 2, Swell 1m

Figure 6. Seaward view from test site.

Operation in conjunction with the APS137 radar at high-power level could have been achieved if preparatory work to provide additional test and validation of the FR8100D receiver front end could have been performed before the tests began. A higher power protection system could have been provided to the radar had the use of the APS137 high-power mode been known beforehand.

4.4.2 Effect

The effect of the constraint on operation was a reduced opportunity to gather data from the scheduled targets and targets of opportunity.

4.4.3 Solution

The limitation was peculiar to the particular test setup and conditions in which the APS137 was directly in line with a radar antenna and at a range of less than 35 m.

Calculations showed that the margin for acceptable power levels at the receiver was very close to damage levels. The possibility of damage during the trials was considered an unacceptable risk and precautions were taken to protect the system during APS137 high-power periods. Subsequent calculation show that considerably more margin exists, and that the front end may be sufficiently rated for the expected shipboard environment.

If the protection proves to be inadequate, the provision of a higher power limiter in the front end of the modified navigation radar will also ensure that abnormal events such as the inadvertent illumination of the system by high-power X band fire control system radars will not adversely effect the front end.

5. PERFORMANCE PREDICTIONS

5.1 PERFORMANCE PREDICTIONS USING BARTON'S MRSAS2 PROGRAM

The radar and processing system configuration was modeled using the MRSAS2 program by D. Barton and published by Artech House (1992). These predictions provide a first-order performance expectation as shown in the plots of figures 7 and 8.

These plots show the cumulative probability of detection for both a 0.3-sqm and 1-sqm target Radar Cross Section (RCS). The cumulative probability of detection (Pd) is the multiscan result of observation of the target traveling radially towards the radar at 4 knots and with a mast exposure of 3 ft. The range at which the cumulative probability of detection is 0.9 is

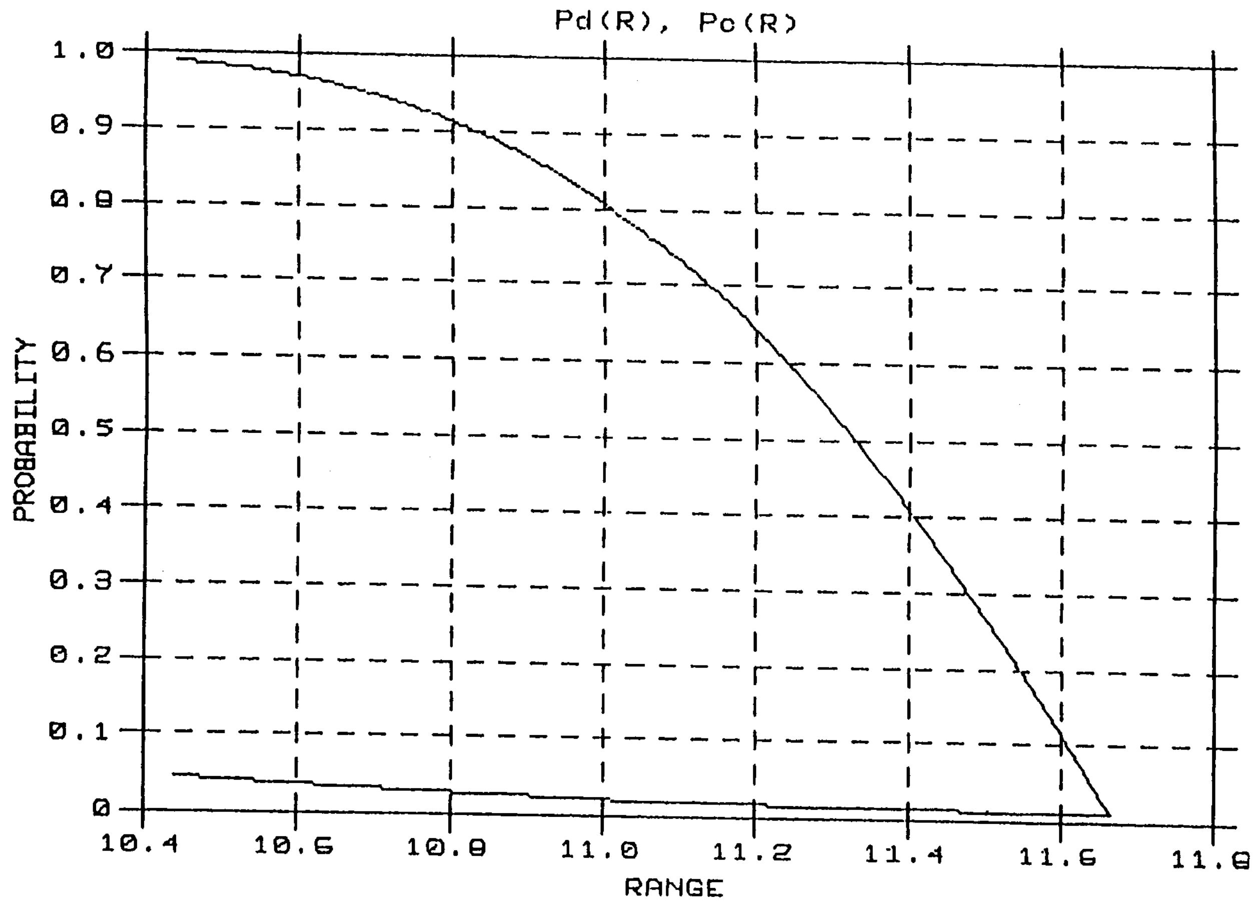
RCS = 1 sqm (0 dBsqm) : range = 10.82 km (11,833 yds)
RCS = 0.3 sqm (–5 dBsqm) : range = 9.46 km (10,346 yds).

5.2 CLUTTER PREDICTION USING THE GIT MODEL

A PC based version of the Georgia Institute of Technology (GIT) sea clutter prediction algorithm was used to predict the mean sea clutter level in dBsqm for sea state 3 and versus range. A summary of these results is shown in figure 9.

5.3 RADAR HEIGHT SENSITIVITY

The height of the radar system was fixed at 34 m above mean sea level (amsl). This height is generally well above the humidity duct height and as such provides no duct advantage for the system. Instead, the height provides a disadvantage for low-surface detection and a higher level of surface clutter due to the higher grazing angles and the refraction into the duct. Typical duct height statistics are provided in figure 10. These statistics are taken from the Ducting Climatology Summary (DCS) Program as supplied by the Naval Command, Control and Ocean Surveillance Center (NCCOSC) Research, Development, Test and Evaluation Division (NRaD), Code D543. These statistics show a typical evaporative duct height of 12 to 18 m, which is well above the target maximum height of 3 m, and far less than the radar height of 34 m. The expected propagation loss factor associated with the target at ranges of 4 to 7 nm is less than 5 dB.



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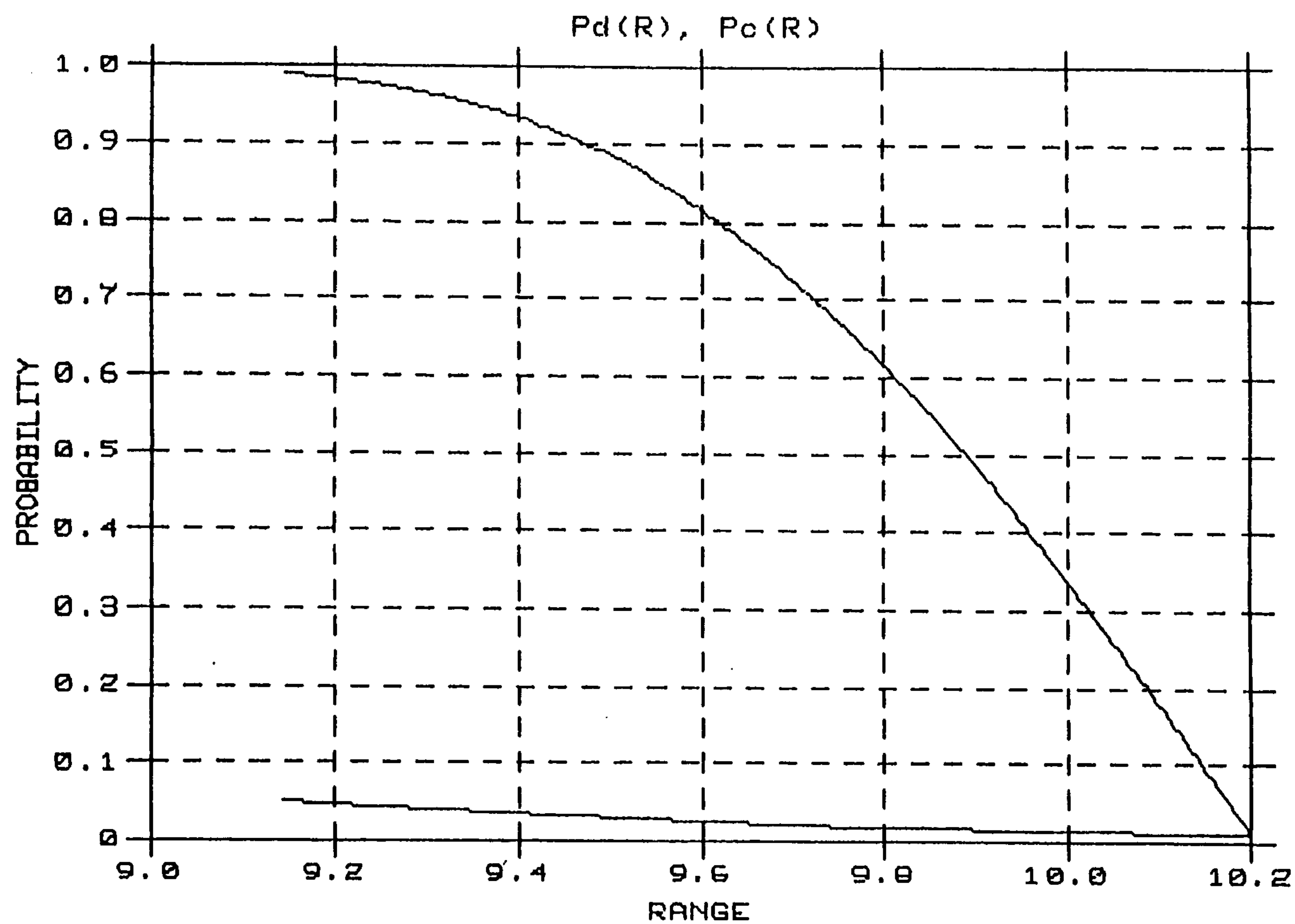
USER: CEA TECHNOLOGIES PTY. LTD.; TIME: SUN MAR 19 16:06:19 1995
VT92\FR8100D.RDR: MODIFIED FURUNO 10KW RADAR WITH 8FT. ANTENNA
VT92\PERISCOP.TGT: PERISCOPE STANDARD TARGET OF 1SQM RCS
DEFAULT\DEFAULT.DET: DEFAULT DETECTION MODEL
VT92\SEASTATE.ENV: SEA STATE 3
DEFAULT\DEFAULT.JMR: DEFAULT JAMMING MODEL (NO JAMMERS)
DEFAULT\DEFAULT.ANL: DEFAULT ANALYSIS MODEL

Figure 7. 1m^2 performance prediction.

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DEFAULT\DEFAULT.DET: DEFAULT DETECTION MODEL
VT92\SEASTATE.ENV: SEA STATE 3
DEFAULT\DEFAULT.JMR: DEFAULT JAMMING MODEL (NO JAMMERS)
DEFAULT\DEFAULT.AHL: DEFAULT ANALYSIS MODEL
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Figure 8. 0.3m^2 performance prediction.

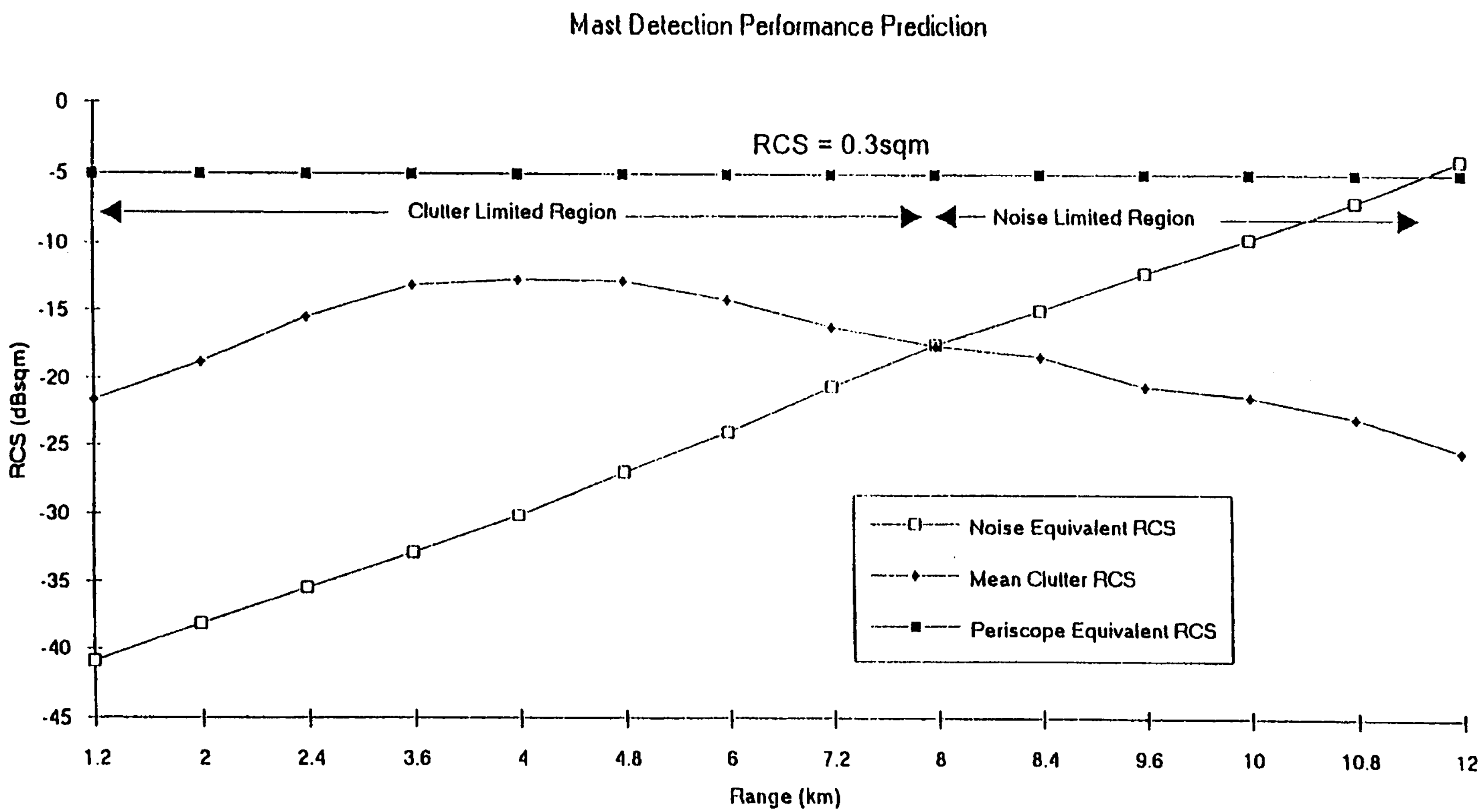


Figure 9. Clutter prediction.

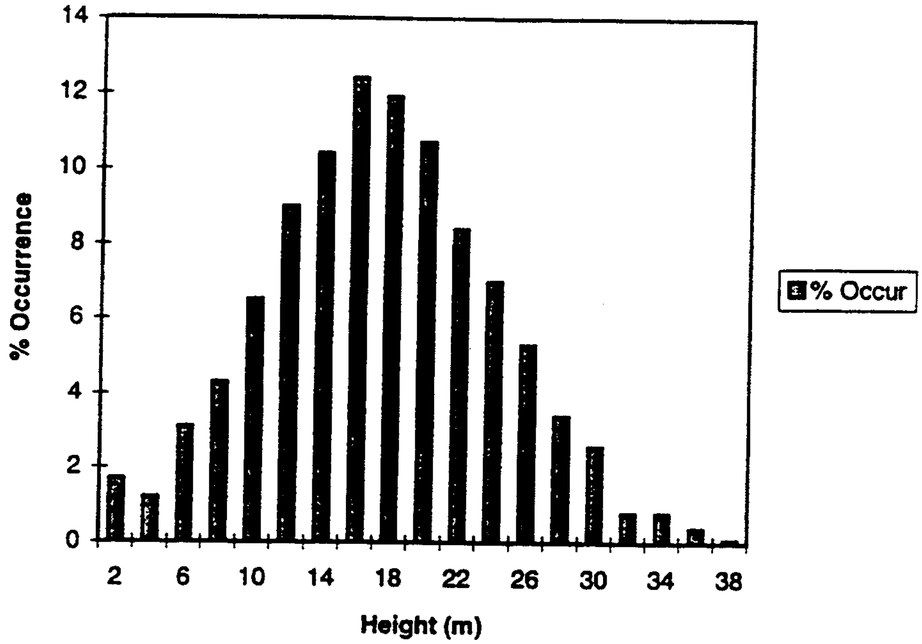


Figure 10. Evaporative duct – Kauai.

6. TEST RESULTS

6.1 RECORDING AND REPLAY SYSTEM

The data recorded for the tests consist of the data passed over the interface between the CEA MIRSS radar processing enclosure and the HP 712 workstation (COTS). These data included:

- surface and air tracks
- single scan plots
- special plots (SPLOTS)
- radar and signal processing system states

In addition, the system records the time of all incoming messages with the exception of single scan plot reports, which are timed in relation to the other message traffic.

These messages and states are recorded in files on the workstation disk as they occur. They are organized into 24 1-hour coverage data sets consisting of 24-hour long files. These files are archived to the digital audio tape (DAT) drive and non-active directories for retention and later analysis.

Replay of the recorded data is available at the workstation to provide a sped up version or a real-time replay of daily runs.

The functional distribution of the mast detection system elements provides a simple and reusable process for the ongoing development and refinement of the algorithm for the track and classification process. This is achieved by having the current track, declaration, and classification processes in the COTS workstation. The input data stream (SPLOTS) recorded to the workstation then allows easy and valid multiple reuse of these data to refine the track and classification process.

6.2 TARGETS

6.2.1 Submarine Target

The submarine target for the tests was USS *San Francisco* (SSN 711). A variety of mast configurations, exposure heights, and times were used and observed.

6.2.1.1 Structured Exposure Runs. These runs were primarily structured for the APS137 data collection process, and consisted of a series of passing runs and octagonal patterns with various mast combinations and exposure heights.

These runs varied from the normal tactical process in both the length of exposure (minutes compared with tens of seconds) and the heights of masts that were generally 2 to 3 times higher than would be used tactically.

6.2.1.2 Tactical Exposure Runs. On 6 December 1994, an opportunity was provided to carry out tactical-type exposures. In this set of runs, the submarine carried out radial approaches and departures over the range bracket 4 to 7 nm.

These runs provided a series of short (15- to 30-sec) exposures of the search and attack periscopes by themselves at tactical heights of 3 to 4 ft. The time between exposures was in the range 2 to 4 min.

6.2.2 Targets of Opportunity

6.2.2.1 Porpoise Tracking. On 6 December 1994, the system showed several unusual surface tracks originating approximately 2 miles from the radar site and moving towards the beach and then, subsequently moving out from the beach. These tracks were visually identified as several porpoise on the surface in calm water. The signal strength associated with these targets was significantly lower than expected from a periscope or mast, but in most other respects had the motion and existence characteristics associated with intermittent mast activity. The ability to track these creatures with such high resolution that adjacent porpoise only 10 to 20 m apart were distinguishable provided a clear and reassuring data point for the sensitivity and performance of the system as set up for the trial.

6.2.2.2 Helicopter Tracking. Numerous opportunities for tracking helicopters were available over the test period. The system, as configured, generally provided good tracking of helicopters to ranges of 12 to 15 nm, and heights ranging from approximately 300 to 2000 ft. Helicopters ranging in size from the environmental data collection unit (Bell Jetranger) to large military helicopters were observed and tracked.

6.2.2.3 P3C Tracking. Several days during the test period, P3C aircraft were operating on the BARSTUR range and provided useful opportunities to track at speeds up to 300 knots with the surface and air track facilities. The automatic detection process proved to be efficient at declaring tracks on the aircraft in low maneuverability conditions. The track process was able to track the aircraft at ranges of 10 to 12 nm, but lost the track in tight maneuvering situations. Enough data were collected to allow analysis and possible upgrade of this capability.

6.2.2.4 Surface Craft Tracking. Multiple opportunities were provided for the tracking of surface craft operating on the range facility. These surface craft varied from the Torpedo Recovery Boats (TRB) to the smaller target craft such as the QST-35 SEPTAR target craft. Other targets of opportunity such as small pleasure craft and a medium-sized Zodiac were tracked.

6.2.2.5 Chaff Exposure. An opportunity to observe chaff deployment was presented on 13 and 14 December 1994 when a large chaff cloud was deployed by helicopters out from Makaha Ridge. This chaff cloud developed to approximately 2 nm by 3 nm and drifted south down the coast.

Observation of the radar returns, with the "non-linear CFAR function" of the MIRSS enclosure turned OFF, predictably produced a large blanked area, and an inability to track the helicopter when coincident with the chaff cloud. Activation of the non-linear CFAR function immediately reduced the chaff cloud to a level that allowed good tracking of the helicopter.

The video displays of figures 11 and 12 show the dramatic effect of the non-linear CFAR in improving the performance of the system with minimal effect on overall sensitivity. CEA claims that this filter function also performs well in rain clouds and some sea clutter conditions.

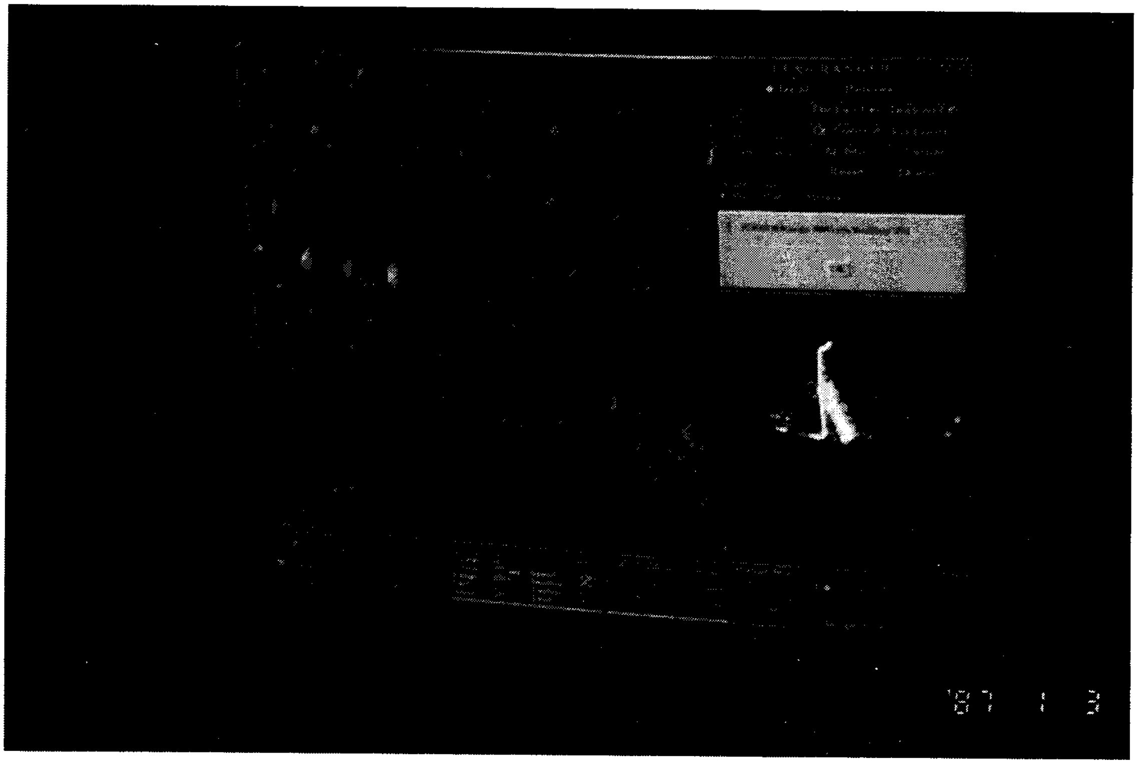


Figure 11. Chaff with normal CFAR activated.

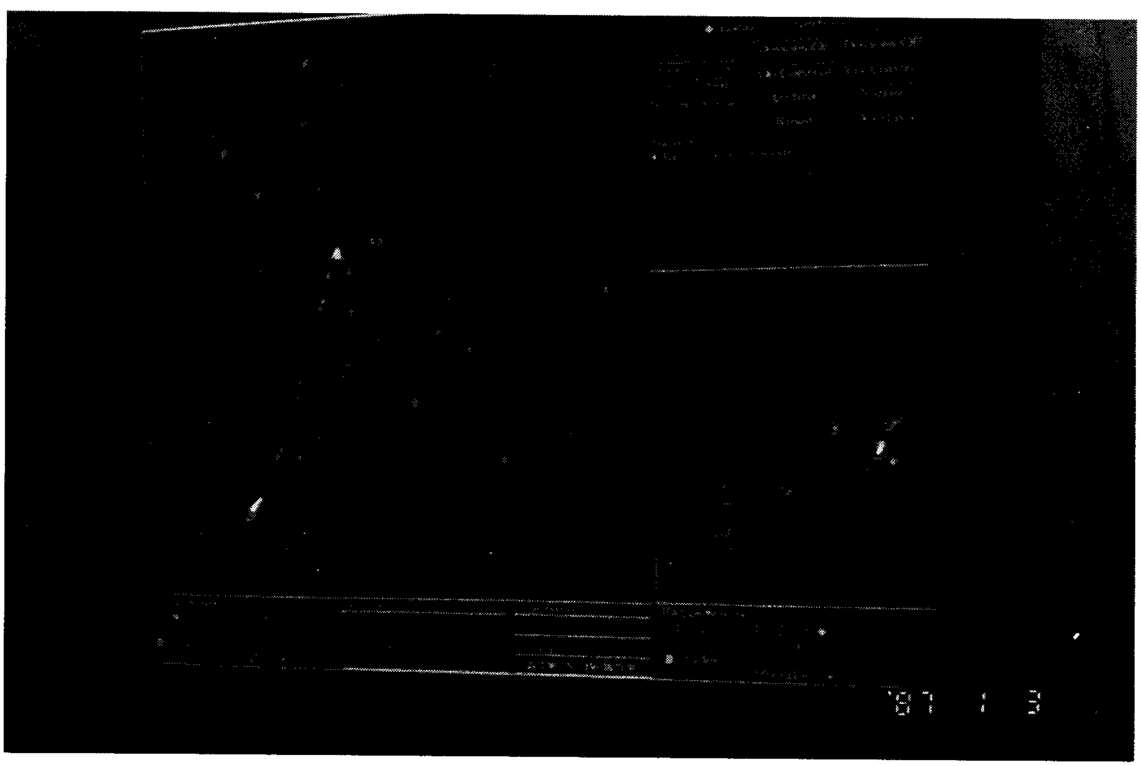


Figure 12. Chaff with non-linear CFAR activated.

6.3 EVALUATION CRITERIA AND RESULTS

The tests conducted attempt to provide meaningful data on the ability of the CEA-SCOPE system to perform the following:

1. Detect mast exposures
2. Classify and discriminate mast exposures
3. Track exposures to derive position and motion estimates on the target

Each of these will be analyzed separately to determine the effectiveness of the system in each category. All data were collected in wave height conditions of 1 to 1.7 m and wind speeds of approximately 6 to 8 knots. These conditions correspond to a sea state of 2 according to the wind speed. The slightly higher significant wave height ($H^1/_3$) is mainly due to swell conditions (White, 1994).

Two sets of data are available: (1) the structured data corresponding to the non-tactical runs performed to gather statistical and signature data and, (2) the tactical runs performed in an attempt to validate the performance of the system specifically in detection and classification of tactical exposures of the search and attack periscope.

Track, time, and depth plots for each structured run (runs 411, 412, 415, 416, 417, and 418) are located in appendix A.

Track Plots

These are the track plots in which the PMRF range measurement data were used to provide a track path for the target. The radar SPLOT data were overlaid on this to show the individual SPLOT reports. The intent of these plots (in appendix A) is to provide an indication of detectability for the radar system versus the range and type of exposure. The absolute range cannot be read directly from the plots. The absolute range is the hypotenuse of the triangle formed by the x and y components on the plots.

Track Plot Type A

The solid line represents the track as provided by the PMRF BARSTUR system. The triangles represent false SPLOTS as detected over the period of the run. The square symbols represent the occurrence of multiple target SPLOTS within the track association gate within an antenna scan. The "det" figure represents the ratio of the total track associated SPLOTS to the number of antenna scans over the duration of the run. The "err" value is the ratio of false SPLOTS to track associated SPLOTS over the run.

Track Plot Type B

This plot shows only the BARSTUR data, single track associated SPLOTS, and false SPLOTS over the duration of the run.

Time Plots

This set of five time plots show the detection, depth, range, detections/scan, and error density as a function of time over the run.

The range plot shows the instantaneous radial range of the target from the radar.

The depth plot shows the instantaneous keel depth.

The detection plot indicates the density of detection areas .

The detections per scan plot shows the averaged detection rate per scan over the time of the run. This is expected to show some correlation with the depth plot. The error density is the number of false SPLOTS (multiplied by 1e6) per second over a square nautical mile.

Depth Plots

This set of two keel depth plots shows the distribution of track associated detections in hits/sec versus depth over the run. For convenience, these plots are broken into two range brackets from 8000 to 12000 yards (3.949 nm to 5.923 nm), and 12000 yards to 16000 yds (5.923 nm to 7.897 nm).

6.3.1 Structured Runs

The plots of runs 411, 412, 415, 416, 417 and 418 were initially analyzed based on the understanding of the configuration as recorded at the time of the test. These, however, may not be the precise mast exposure configurations as it has not been possible to obtain the final confirmation of configuration data.

Run 411

This run had the target on an octagon path centered at a range of approximately 12000 yards from the radar site.

The mast configuration was a 9-ft exposure of the search mast.

Detection at ranges to 13596 yards was obtained with the target aspect beam on.

Detection at ranges beyond 11500 yards with the target in a bow aspect was intermittent.

Detection at ranges less than 11200 yards was consistent.

Keel depth varied by more than 20 ft over the length of the keel.

Run 412

This run had the target on an octagon path centered at a range of approximately 12200 yards from the radar site.

The mast configuration was a 9-ft exposure of the search mast.

Detection was obtained on the combined mast exposure to ranges of 13330 yards with high densities of returned data at all profiles.

Run 415

This run had the target on an octagon path centered at a range of approximately 13000 yards from the radar site.

The mast configuration was an 11-ft exposure of the search mast.

Detection beyond 12800 yards was not obtained with the exception of two multiple SPLOT detections at ranges of 14673 yards and 14166 yards.

Run 416

This run had the target on an octagon path centered at a range of approximately 13000 yards from the radar site.

The mast configuration was a 9-ft exposure of the search mast.

Sparse detection at all ranges was obtained on this exposure, with results showing some detections at ranges as far away as 14100 yards and others at closer ranges.

The radar tuning function was not performing correctly at this time, which may account for some of the inconsistency of this run's results with the results of the other runs.

Run 417

This run had the target on a straight path running towards the radar site at a start range of approximately 11700 yards.

The mast configuration was an initial 11-ft exposure of the search periscope decreasing over the length of the run to no exposure.

Detection at ranges of 11700 yards was obtained, but as the mast was progressively pulled down, the detection density decreased and was lost at a range of 11240 yards where the mast height is estimated at less than 4 ft.

Run 418

This run had the target on straight path running north to south.

The mast configuration was a 7-ft maximum transient exposure of the search periscope. Several distinct exposure detections were obtained over the run, but sufficient data were not available to correlate these with the detection opportunities.

6.3.2 Tactical Runs

The tactical runs conducted on 6 December 1994 were comprised of short exposures of the search and attack periscopes with the submarine running on radials to and from the radar position over range brackets of 4 to 8 nm. These runs were not supported by track data from the PMRF range. During these runs, minimum exposures of the mast were used to simulate tactical use of the periscope. These exposures were staged for between 15 and 30 seconds at approximately 3-min intervals. The SPLOT returns from these runs are shown in replayed form on the screen dumps in appendix B. They were produced from screen dumps from the CEA-SCOPE software and show the SPLOTS as small circles. These SPLOTS were the result of clustered multiscan detections consistent with a mast exposure.

Two forms of screen dump are provided:

1. Plots of all SPLOTS accumulated over the period of the run
2. Plots of those SPLOTS associated with declared submarine tracks only

Some of the plots have been timed to show the track and alert generated by the SPLOTS and representing a level 1 alert.

The radar site is marked by a small circle with a coincident cross on the land to the right of the geographic displays. Small crosses, indicating 1-nm markers, are shown on the radial of 280 degrees.

The tactical runs were conducted with the target on an approximate radial and conducting tactical exposures of the search and attack periscope at approximately 3-min intervals. These exposures were for periods of 15 to 30 sec and to a tactical height of just 3 ft.

SD 1 shows the accumulated SPLOTS collected over a 2-hour period, with the submarine coming from the north to turn onto the radial and commence the tactical run. During the transit to COMEX, the submarine had its communications mast exposed, and solid SPLOT returns are evident over most of the pre-run positioning process.

At COMEX, the target commenced the short exposures, which produced six distinct individual mast detection opportunities between 4 and 5 nm.

The accumulated band of CLUTTER SPLOTS was as a result of the wave structure associated with diffraction around the island and which created a significant wave structure with steep leading edges advancing to shore. Although the clutter SPLOT density on screen seems large, the actual density with time is very small, and only one level 1 alert was created in this general area over a run period of 2 hours.

SD2 shows the accumulated SPLOTS collected over a 20-min period on an inbound tactical run. The clutter SPLOTS again show a significant band in the region of the wave diffraction effects at a range of approximately 3 nm. The target SPLOTS show a total of six tactical periscope exposures over the range bracket 5.2 to 4.3 nm, and a communications mast exposure at the end of the run as the target turned to depart the range to the west.

SD3 shows those SPLOTS associated with declared classifications of mast exposures. Of the six detection opportunities that show significant SPLOT returns, five produced level 1 alerts, with the third detection opportunity being missed at a range of 4.8 nm due to insufficient data.

SD4 shows a typical level 1 alert at a range of 8855 yards on a bearing of 274 degrees. The alert is shown in the window near the top of the right-hand side of the screen. The current track data parameters are shown in the "Track Data" window at bottom center of the display.

Fourteen detection opportunities were offered in the two sets of runs between the ranges of 4 and 5.2 nm. These 14 detection opportunities all present SPLOTS for analysis with the exception of two. The data available produced ten level 1 alerts. This represents a probability of correct detection and classification of 0.71 over the range bracket 4 to 5.2 nm. The probability of detection based on the availability of SPLOTS is higher at approximately 0.86.

More detection opportunities were presented at ranges beyond 5.2 nm (10535 yards), but these did not produce significant SPLOT returns. The performance of the radar system is not expected to show such returns beyond the predicted performance range of 10390 yards for the single periscope exposure.

6.3.3 Other Data Runs

Over the 2-day period, some other data were recorded, but were either contaminated by the radar tuning problem identified in section 4.1 of this report, or had limited scope due to shutdowns to avoid damage from the APS137 in high-power mode.

6.3.4 Conclusions

6.3.4.1 Detection. The detection of mast exposures is a product of the following significant factors:

1. Radar antenna gain
2. Radar effective radiated power
3. Radar effective sensitivity
4. Radar signal processing
5. Radar height
6. Ducting and propagation factors
7. Target radar cross section and exposure height

The performance predictions provided in section 5.1 and figure 8 show that the radar used should be capable of detection performance to approximately 9.5 km (10390 yards) on a 0.3-sqm RCS target at a height of 1 m and in sea-state 3. The test results were analyzed to provide detection opportunities based on the known path of the target. The analysis used a data gating technique that provided plots of special plot data (SPLOTS) corresponding to time and spatial correlation with the known track. The gating technique used a 500-yard square acceptance box around the known position to reject data outside the area of interest. The radar accuracy and range data should be able to be correlated to better than 50 yards, based on the known sensor performance. Any clutter-generated SPLOTS outside this area are not shown on the track plots. As can be seen from the data plots in appendix A, the resulting false SPLOTS rate is very low.

The detectability results of the analyzed runs show that minimum height mast exposures at ranges less than 10000 yards are likely to be very vulnerable to detection, and that more significant mast exposures, both multiple masts and higher exposures heights, are likely to be detectable to ranges out to 14000 yds or beyond with reasonable probabilities. The tactical run results are particularly revealing as the system showed a high level of confidence at ranges to 10000 yds on very short and minimum height exposures. These numbers fit with the predicted performance as provided in the previous section where reliable detection to 12000 yards on a 1.5-m search periscope exposure is predicted.

6.3.4.2 Classification and Rejection. The classification, as applied to the structured runs, is not as relevant as the tactical runs where the exposure time was short and more typical of submarine tactical behavior. This was not the case in the structured runs where the data often presented continuous (tens of minutes) tracking opportunities that led to declassification of the exposure as a mast exposure and reclassification as a surface target. The classification process, as applied to the tactical runs of 6 December 1994, are shown by the SPLOT screen dumps for the tactical runs in which only those SPLOTS associated with declared submarine tracks are put to screen. The number of successful detections (as indicated by significant SPLOT returns) and classifications between the ranges of 8000 and 10530 yards was 14 in an inbound and an outbound run. The number of missed detection opportunities is assessed as 2 and the number of missed classifications as 4. Although the number of opportunities is relatively low, the numbers are suitable for providing indications of the success and false alarm rates to be expected. This provides an initial assessment of the detection probability of better than 0.8 and an initial assessment of the classification probability of better than 0.7. One false classification was generated during a 2-hour observation period.

6.3.4.3 Tracking. The tracking functions are yet to be analyzed for the structured runs. Note that manual observation of track data for all declared mast exposures in both the structured and tactical runs generally gave the course to within ± 30 degrees on the first alert for the track, and the speed to within ± 3 knots. These alerts occurred within 15 sec of the first SPLOTS available for processing.

7. CURRENT SYSTEM LIMITATIONS

The trials system used for this test was configured for fixed installations only because the vessel stabilization routines have not been fully implemented. These stabilization processes have been defined and are in the process of implementation. They will provide data correction for all significant ship motion effects including:

1. Ship's pitch and roll induced parallax effects
2. Ship's pitch and roll induced tilt errors
3. Ship's course and speed instantaneous effects
4. True motion effects

The software version used in the test was not configured with the multiple exposure algorithm that has the potential to both increase the probability of detection and correct classification.

8. POSSIBLE IMPROVEMENTS

8.1 AIR TRACKER DYNAMICS

The ability of the existing tracker to effectively follow tight air target maneuvers is limited by the scan rate of the antenna and the requirements to follow lower speed targets. Some improvements in this aspect were identified and will be implemented and validated at the earliest opportunity. The higher rotational rates of the antenna system will improve the air target tracking ability through more updates during high-speed maneuvers, and can be complemented by algorithms more adapted to tight turns on fast targets.

8.2 LONG-RANGE SURFACE TARGET DETECTION PROCESS

The test provided an opportunity to examine the long-range surface detection process on marginal targets of limited and intermittent visibility. This has lead to a strategy for the improved detection and classification of such tracks and this strategy will be implemented and tried at the first available opportunity.

8.3 FALSE ALERT DISCRIMINATION PROCESS

The two-level alert system summarized in figure 4 should provide a staged alert confidence on detections. This information, combined with appropriate procedures, should allow for high probability of detection and confidence with low false alert rates in sea states up to SS 3. Further work is possible in the area of discrimination of mast exposures from the small dimension surface objects that may produce level 1 alerts. This work will use the data collected during this trial to extend the initial classification algorithms, and should be able to provide a significant improvement in level 1 false alert rates.

9. SUMMARY

1. The preliminary results of the analyzed data for both structured and tactical runs shows the MIRSS radar and CEA-SCOPE detection algorithms are capable of both detection and classification of short mast exposures to predicted ranges of approximately 10000 yards.

2. The predicted performance matches closely with the measured performance for minimum height single search or attack mast exposures. Exposure of other mast configurations and at larger heights allows detection to ranges of at least 14000 yards.

3. The 0.7 probability of successfully classifying a mast exposure appears to be good, provided an exposure time of 15 sec or more is available. This was evident even with the operational limit on the radar for rotation rate and PRF in which both were limited by a fault to approximately 50% of the desired rates.

4. Based on the short tactical exposures experienced, the overall probability of successful detection and classification at ranges between 6000 and 10000 yards appears to be at least 0.7. There is significant opportunity to improve this figure due to the availability of somewhat better detection opportunity data (Pd = 0.86) and with the incorporation of the multiple exposure algorithm to take account of these.

APPENDIX A

ANALYZED RESULTS FOR RUNS 411, 412, 415, 416, 417, AND 418

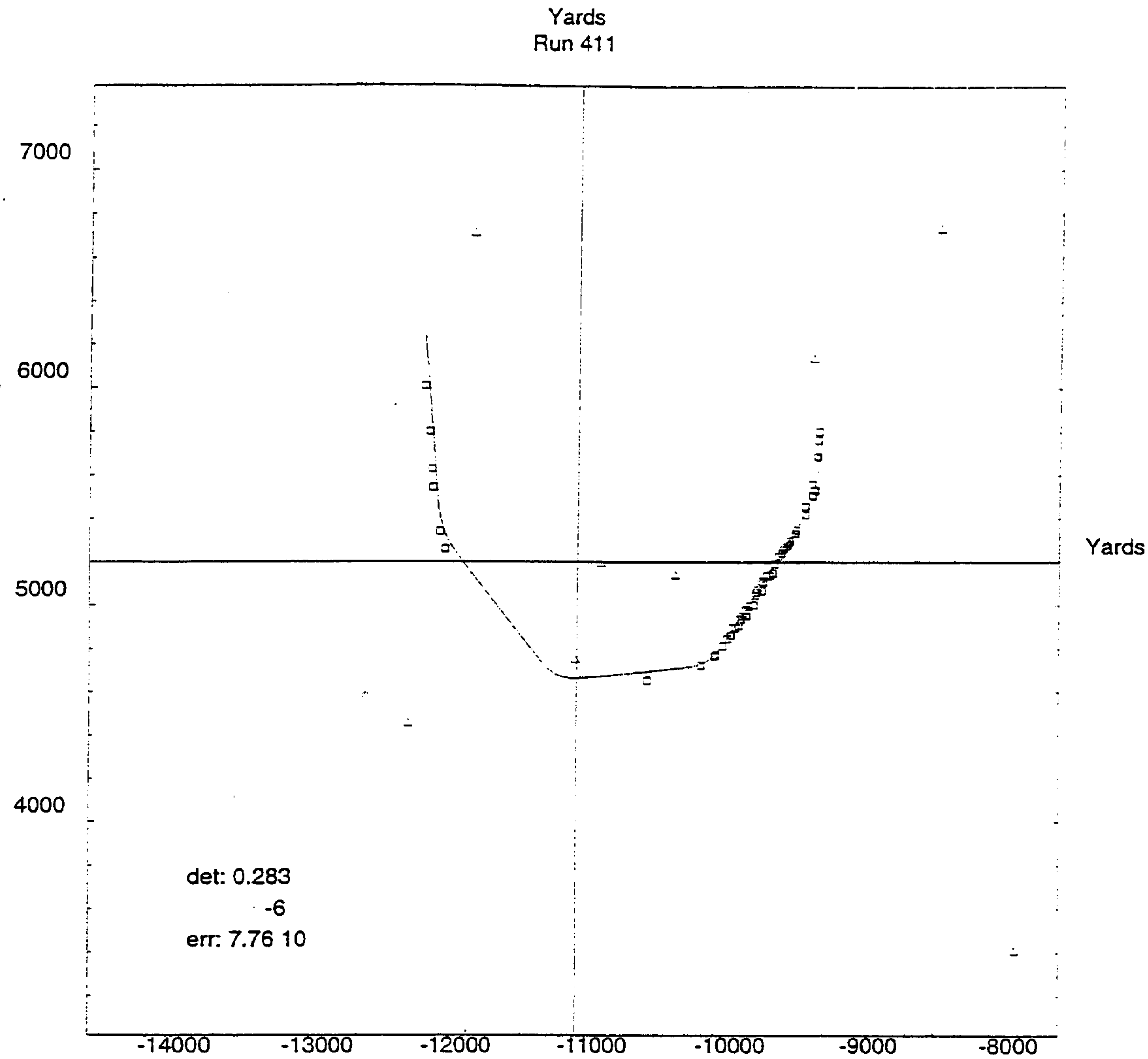


Figure A-1. Run 411, track plot type A, exposure type – search mast at 9 ft.

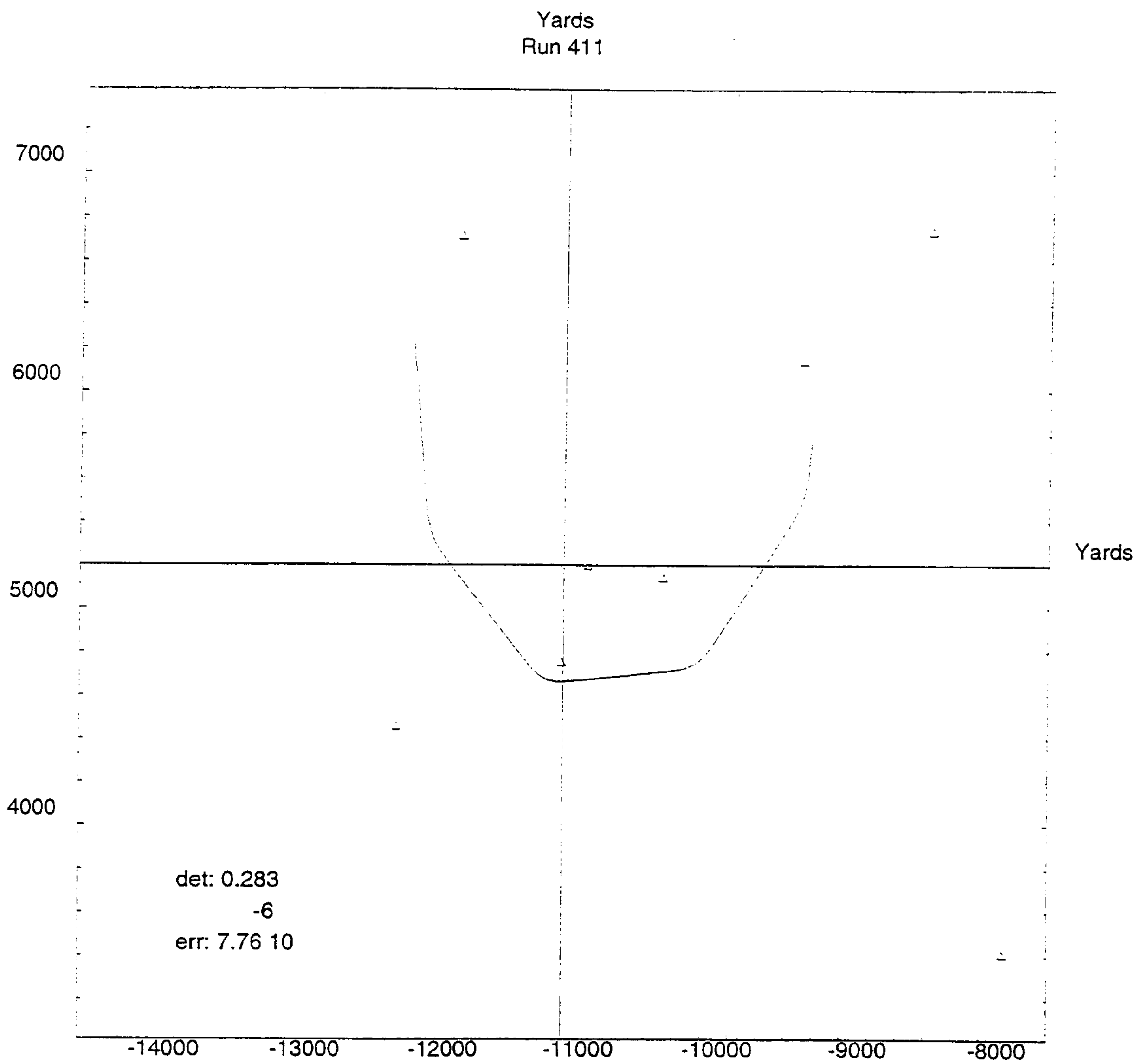
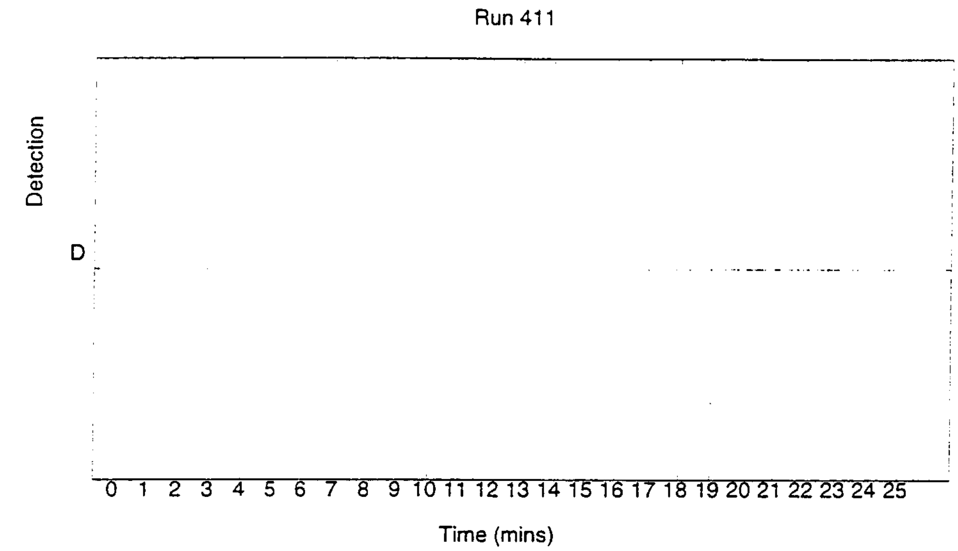


Figure A-2. Run 411, track plot type B, exposure type – search mast at 9 ft.



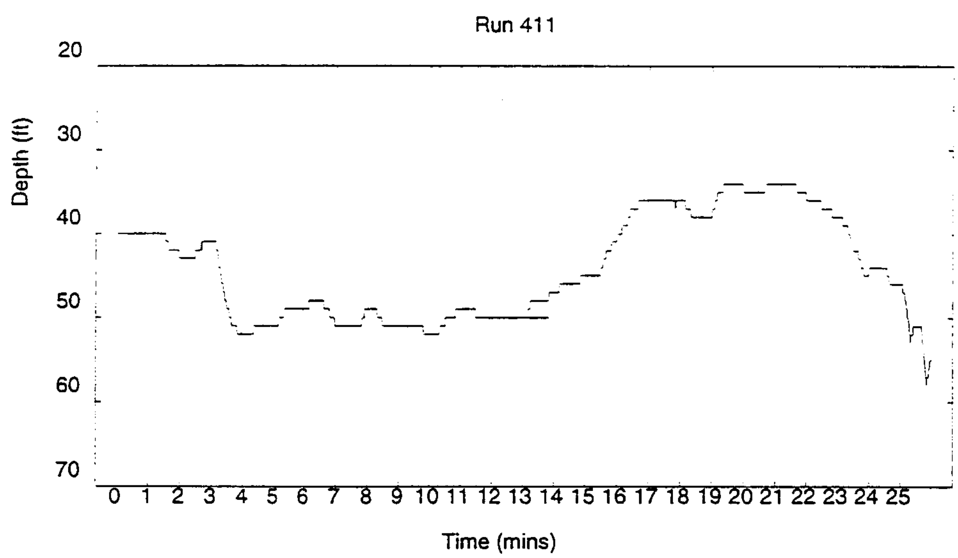
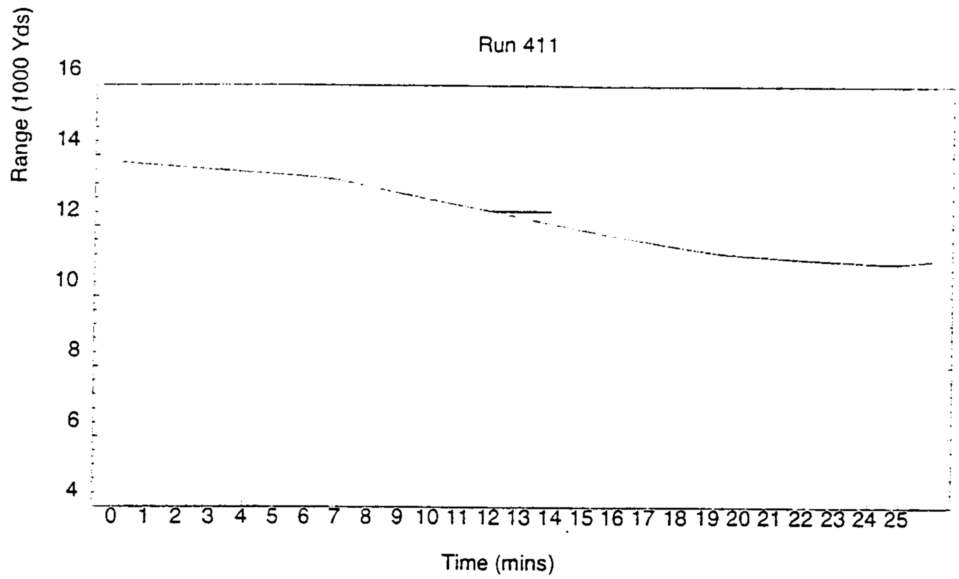


Figure A-3. Run 411, time plots, exposure type – search mast at 9 ft.



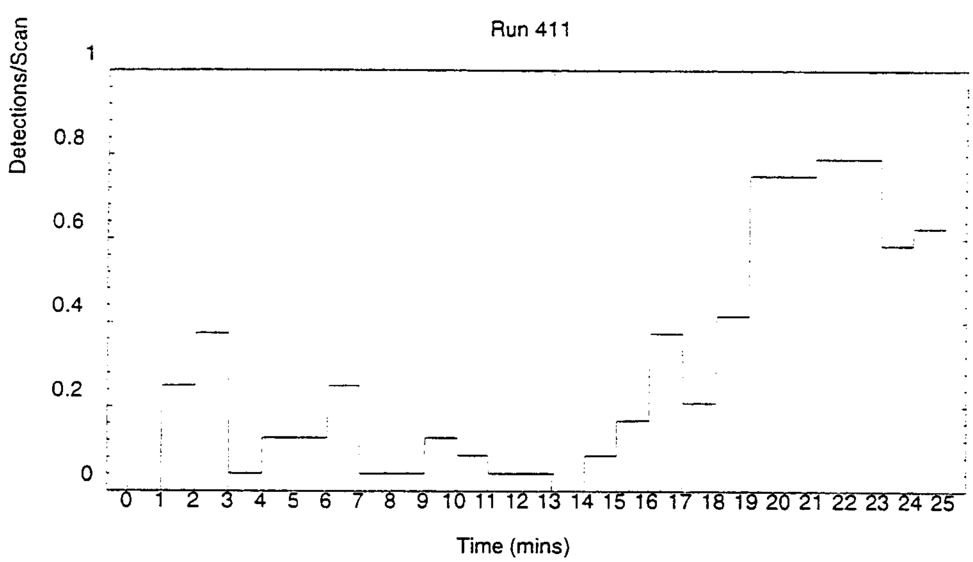


Figure A-3. Run 411, time plots, exposure type – search mast at 9 ft (Cont).

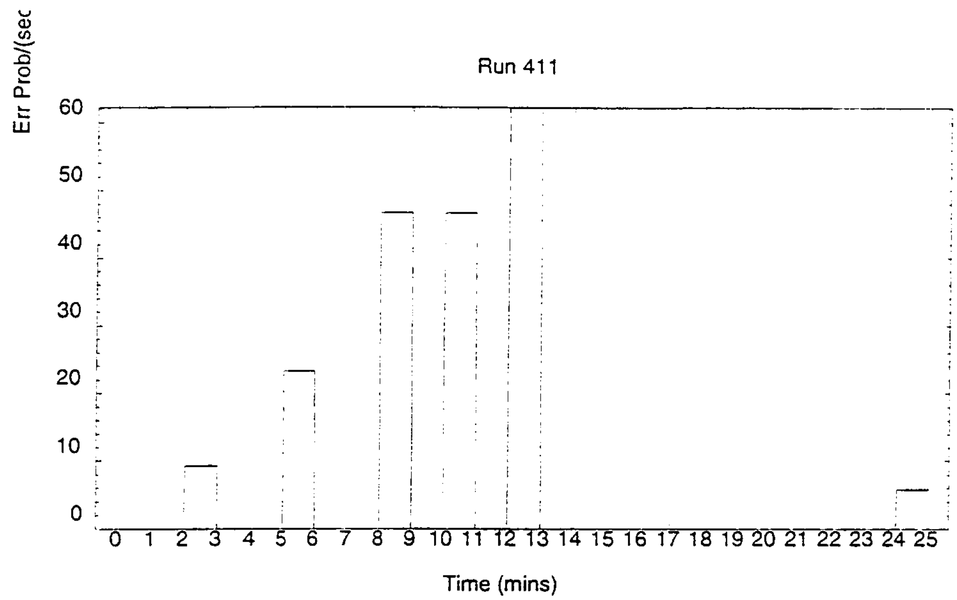
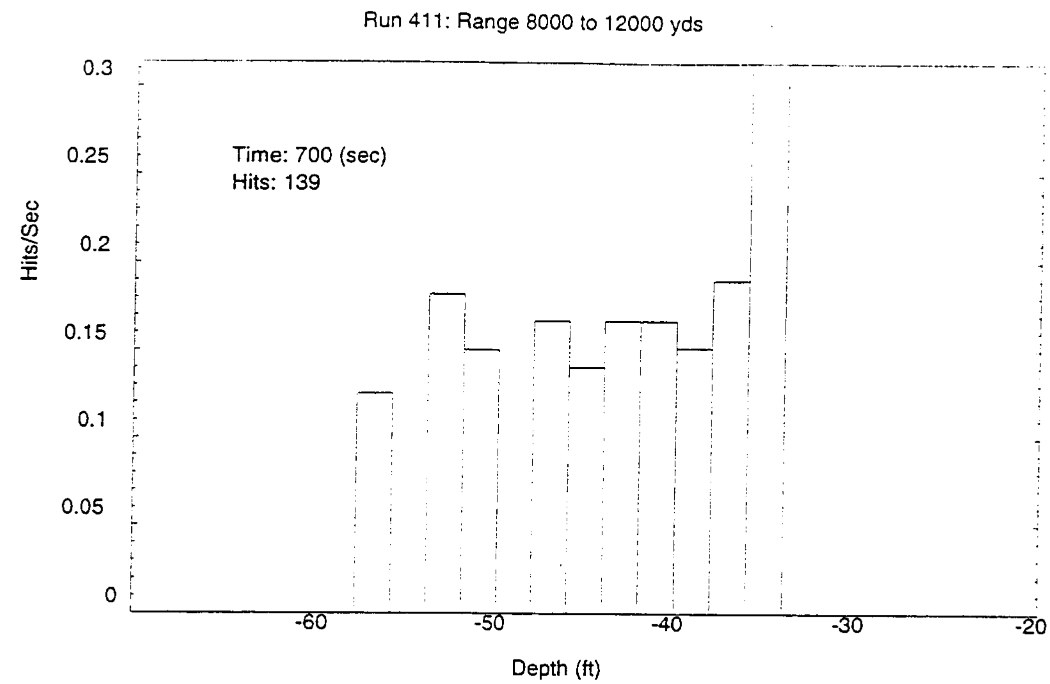


Figure A-3. Run 411, time plots, exposure type – search mast at 9 ft (Cont).



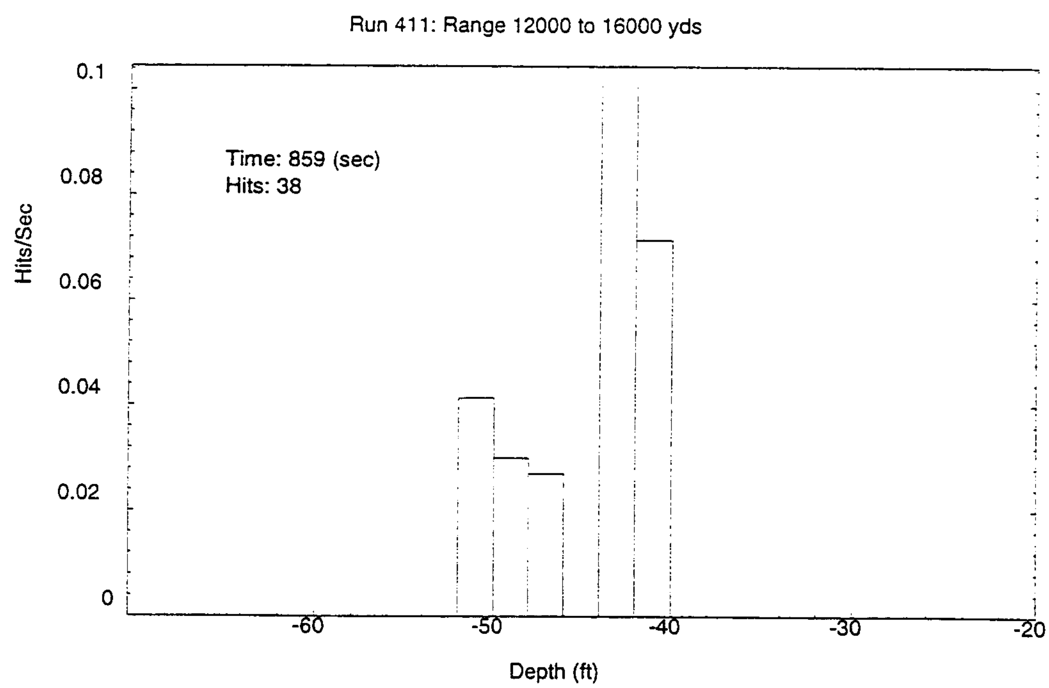


Figure A-4. Run 411, depth plots, exposure type – search mast at 9 ft.

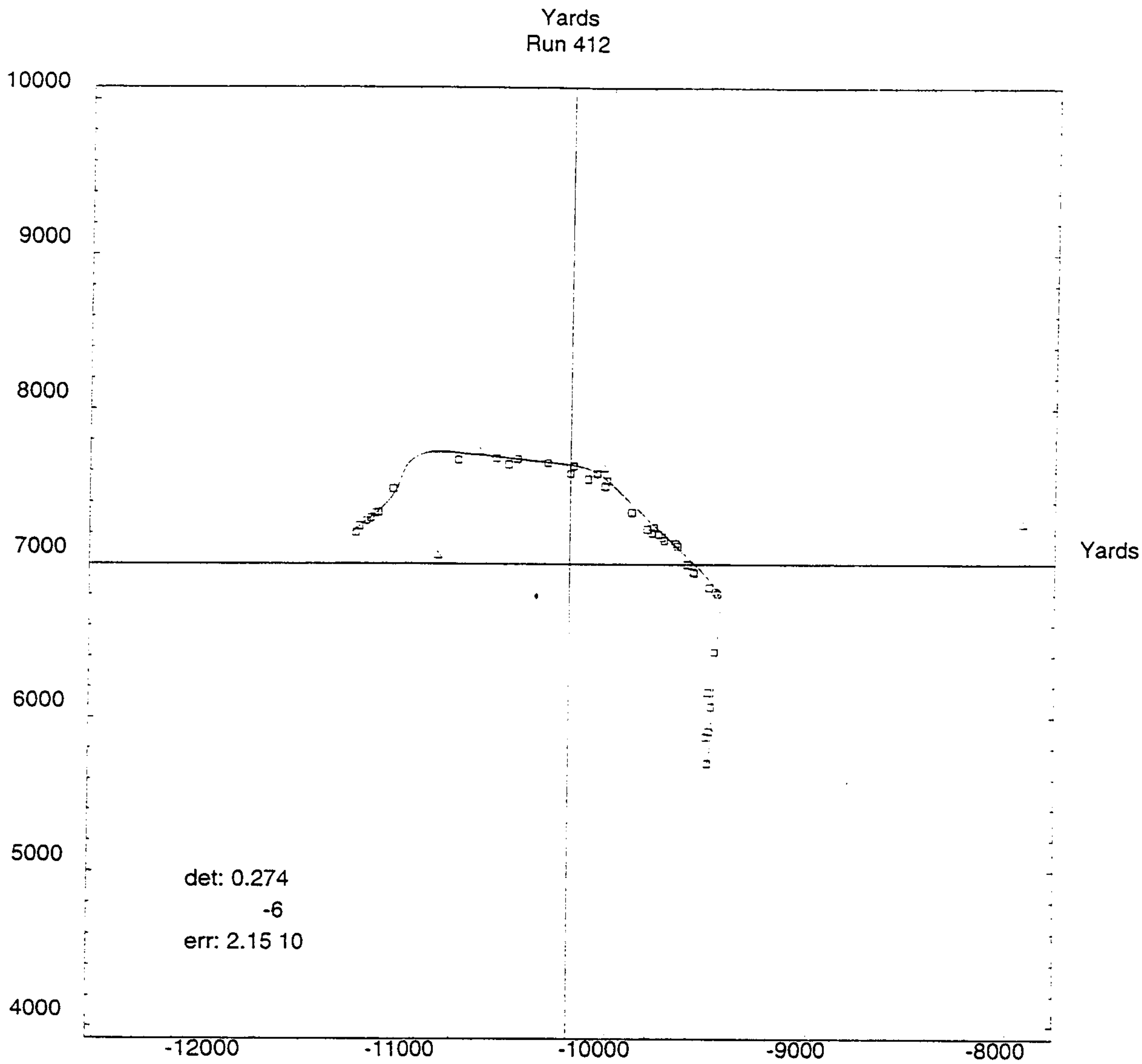


Figure A-5. Run 412, track plot type A, exposure type – search mast at 9 ft.

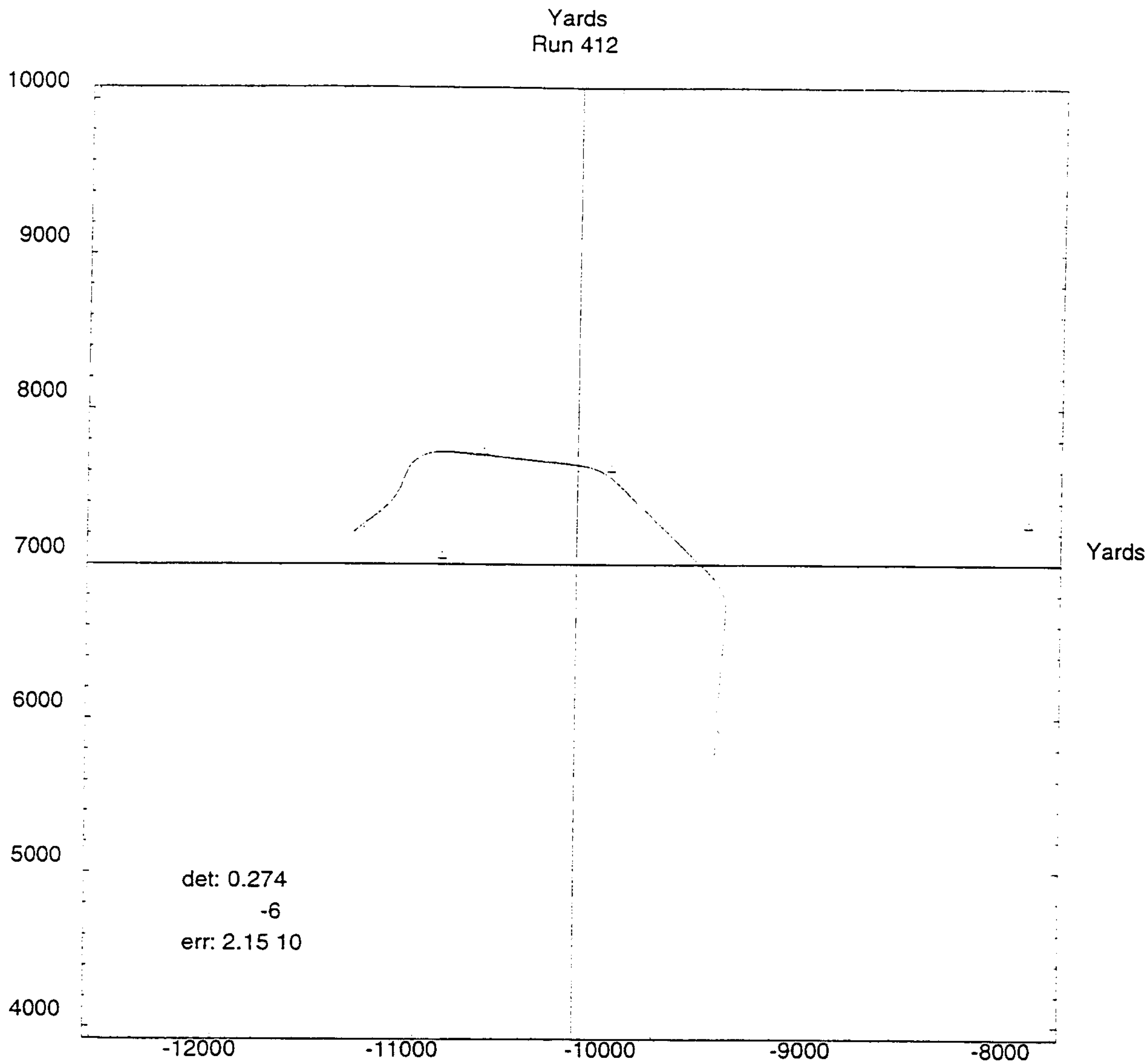
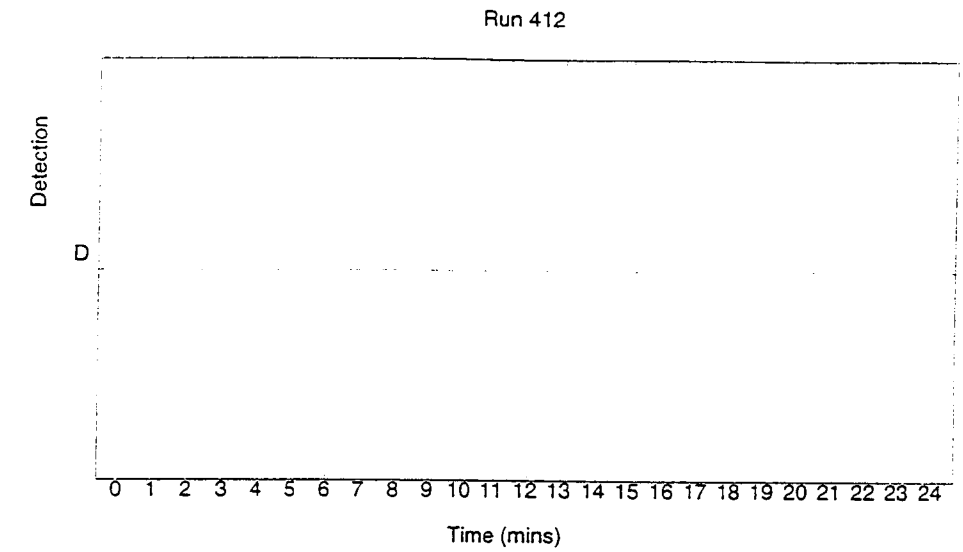


Figure A-6. Run 412, track plot type B, exposure type – search mast at 9 ft.



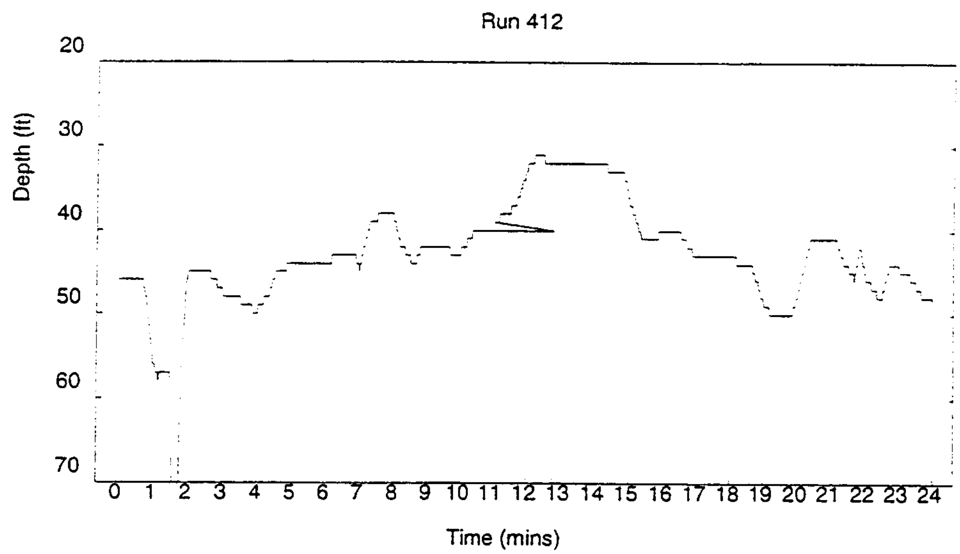
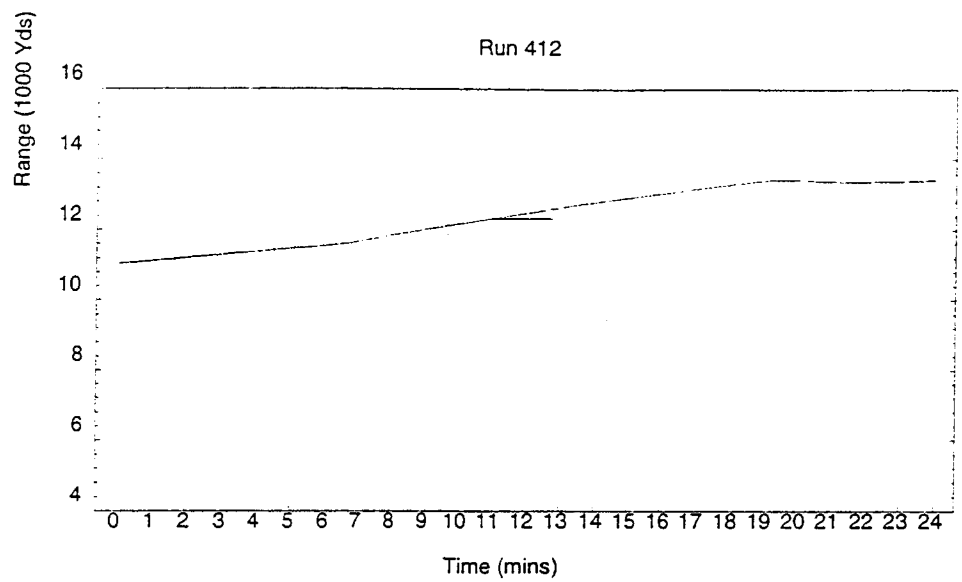


Figure A-7. Run 412, time plots, exposure type – search mast at 9 ft.



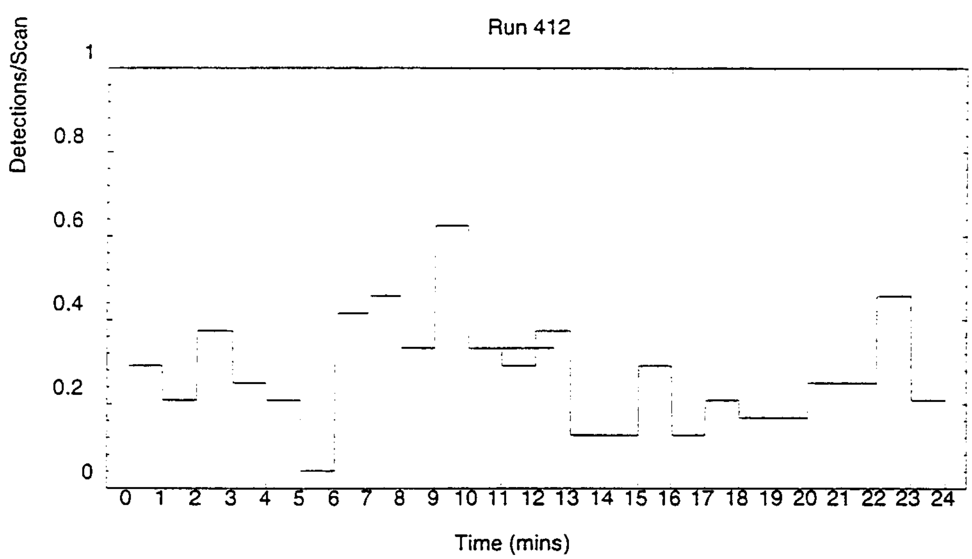


Figure A-7. Run 412, time plots, exposure type – search mast at 9 ft (Cont).

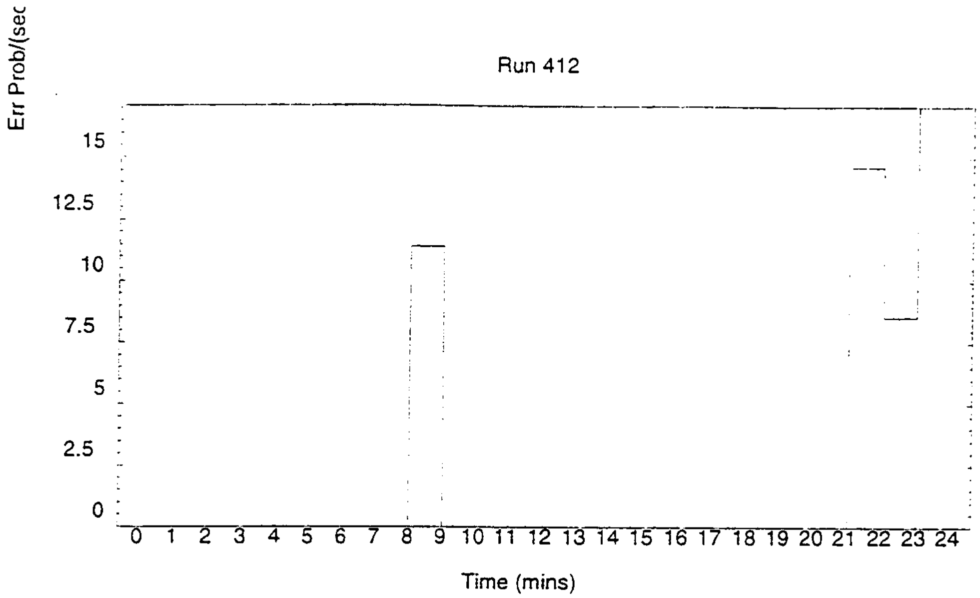
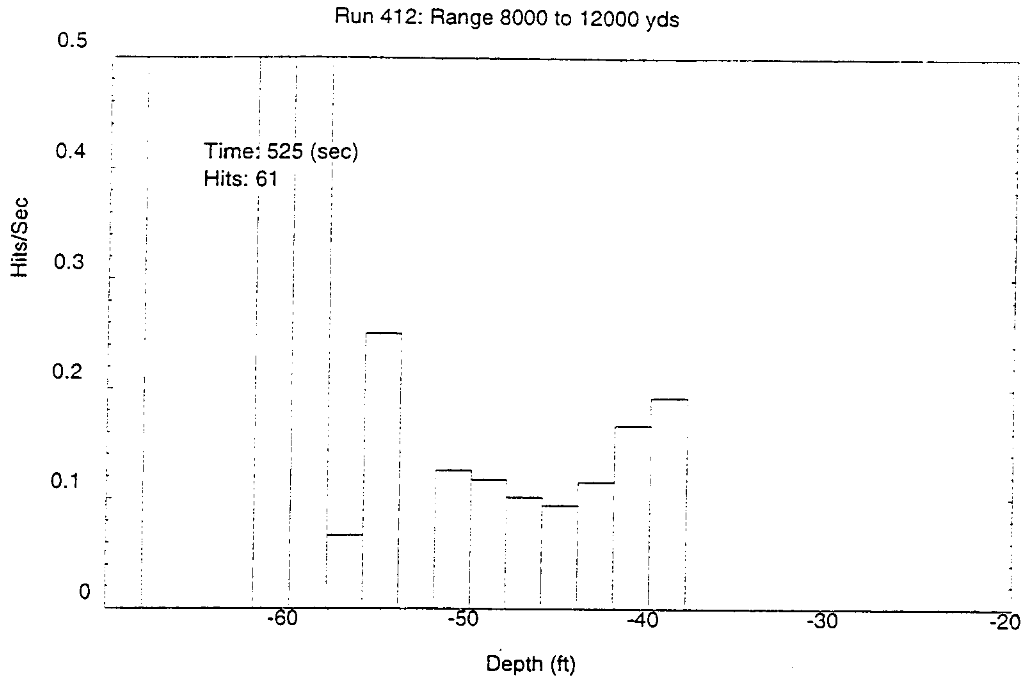


Figure A-7. Run 412, time plots, exposure type – search mast at 9 ft (Cont).



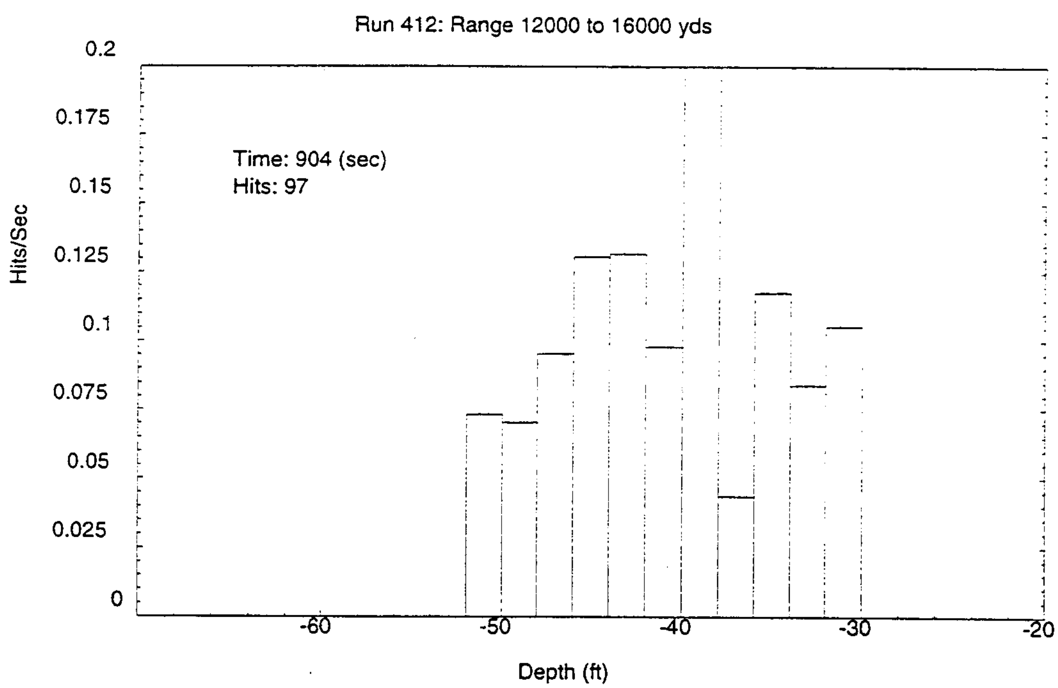


Figure A-8. Run 412, depth plots, exposure type – search mast at 9 ft.

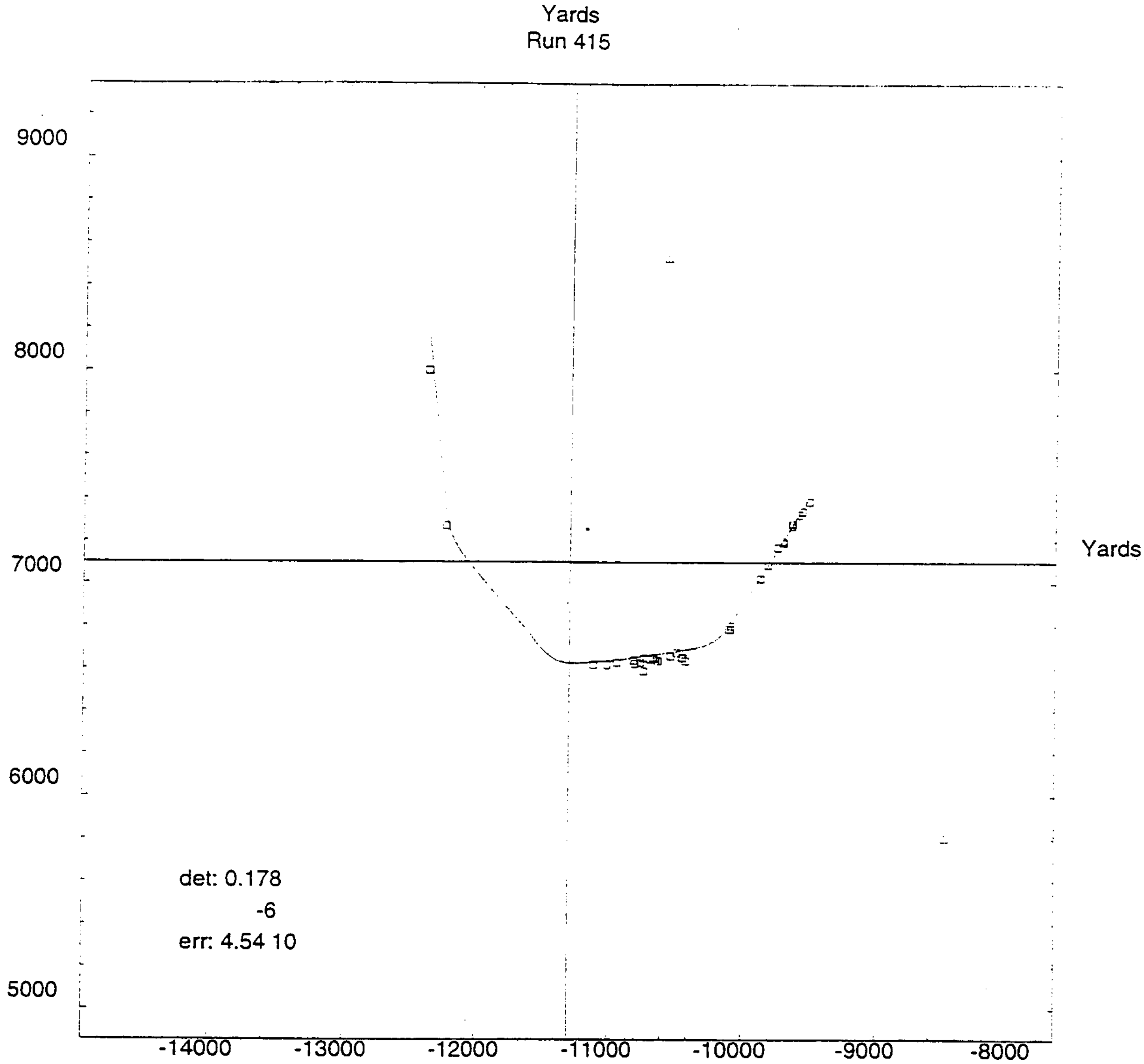


Figure A-9. Run 415, track plot type A, exposure type – search mast at 11 ft.

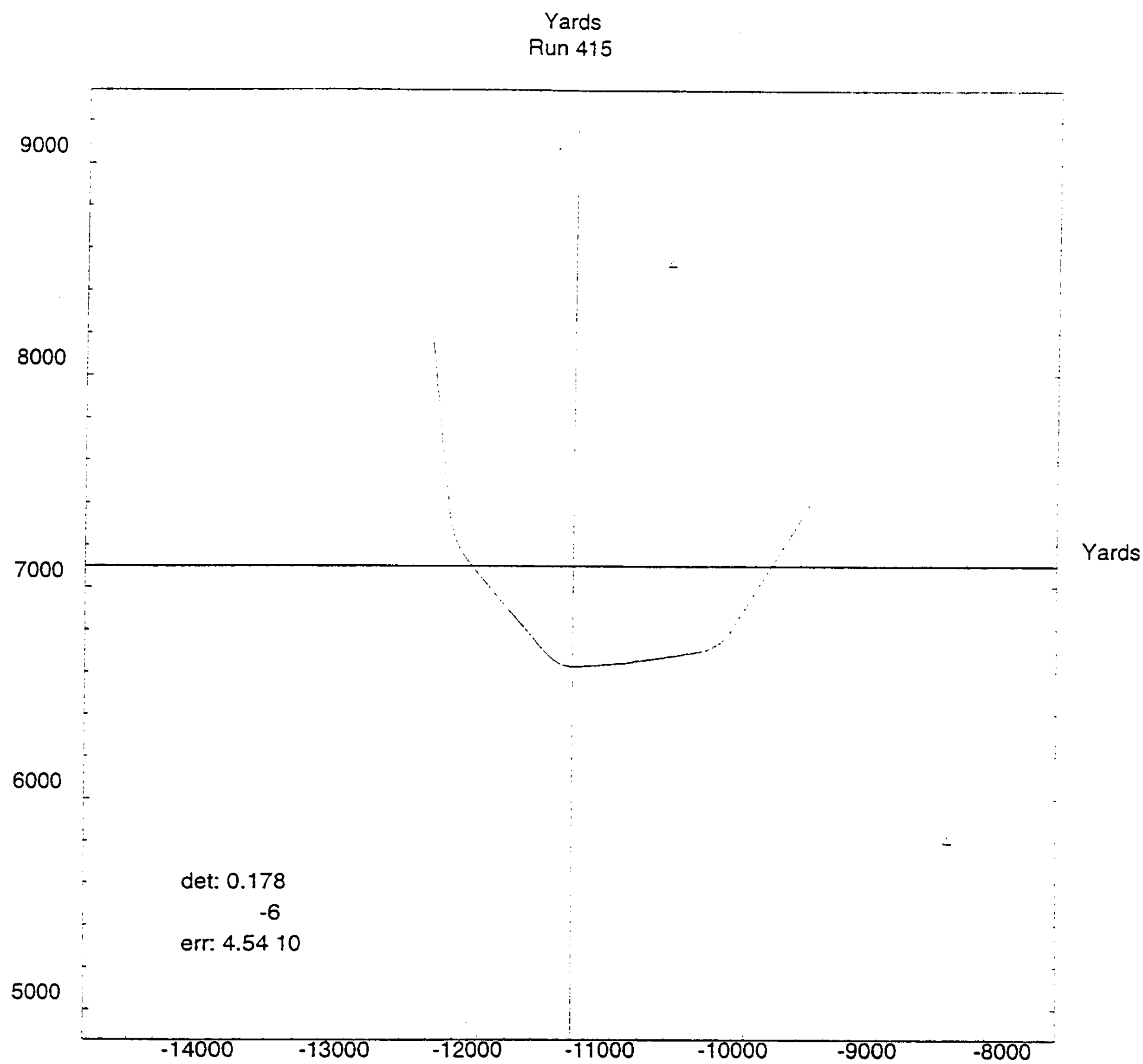
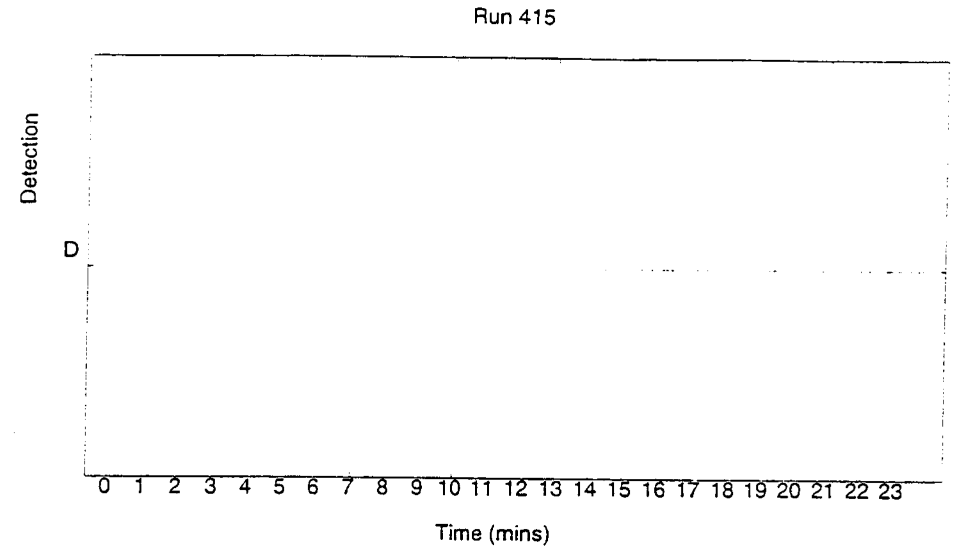


Figure A-10. Run 415, track plot type B, exposure type – search mast at 11 ft.



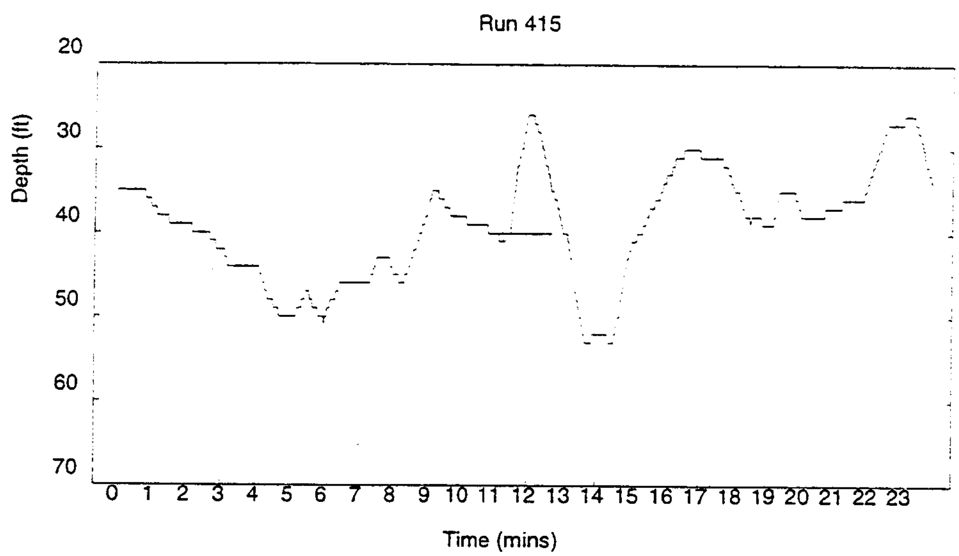
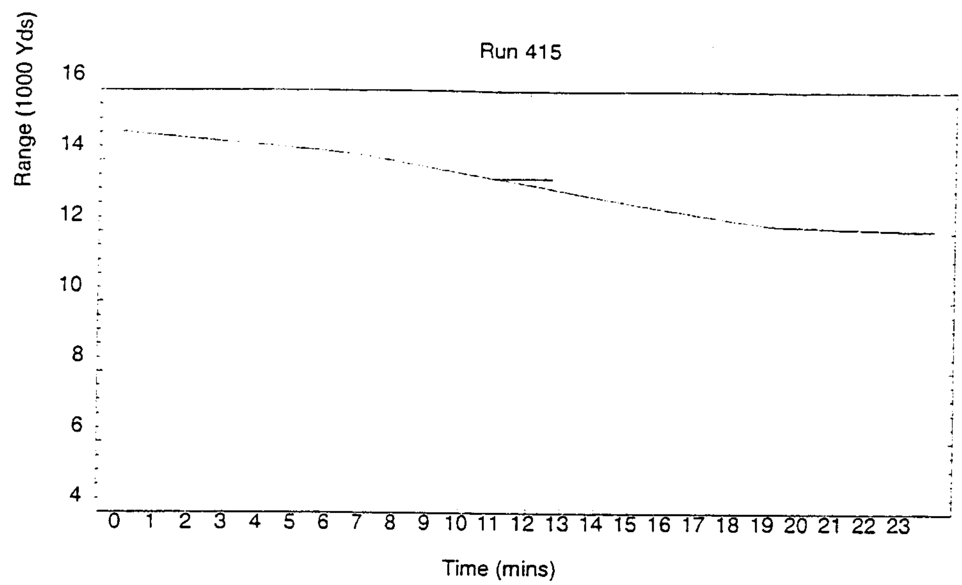


Figure A-11. Run 415, time plots, exposure type – search mast at 11 ft.



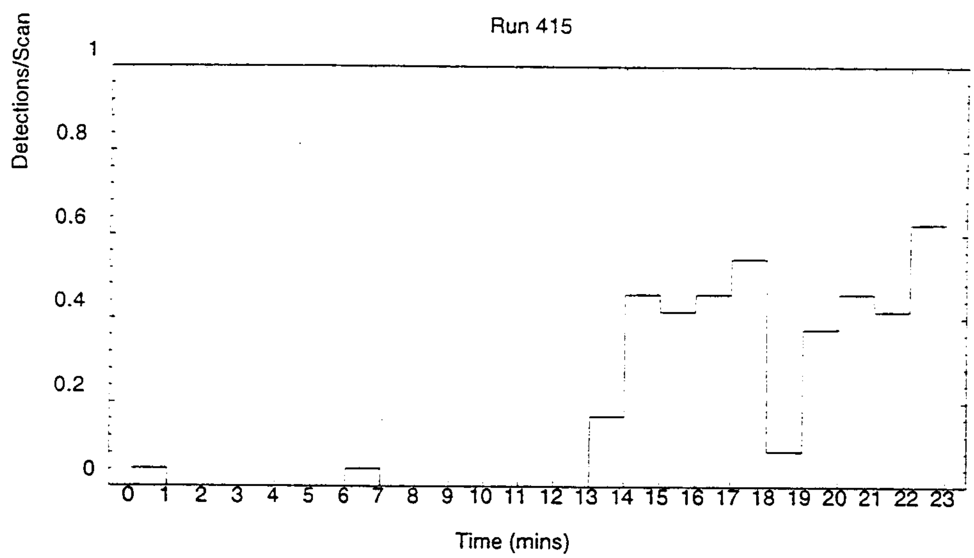


Figure A-11. Run 415, time plots, exposure type – search mast at 11 ft (Cont).

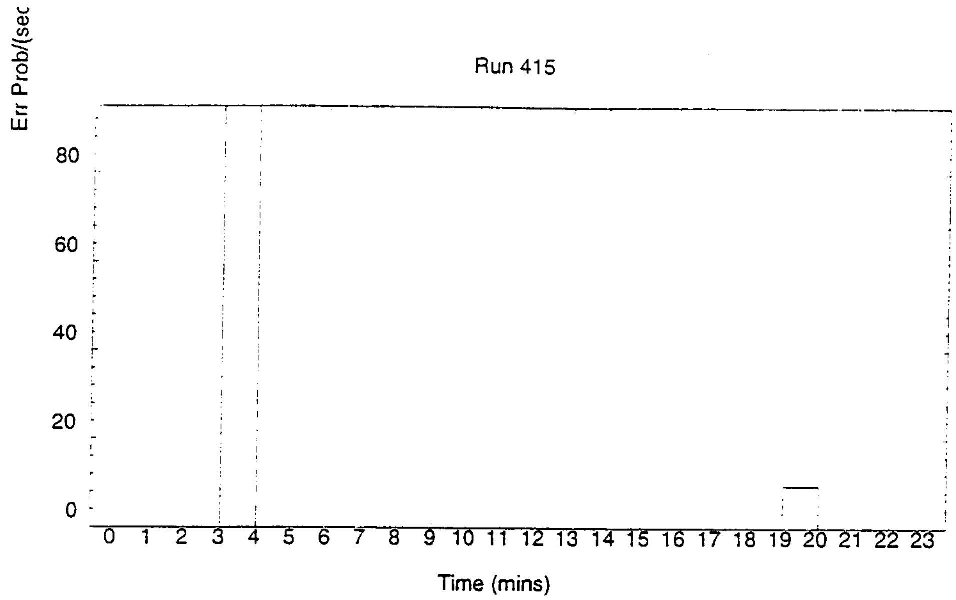


Figure A-11. Run 415, time plots, exposure type – search mast at 11 ft (Cont).

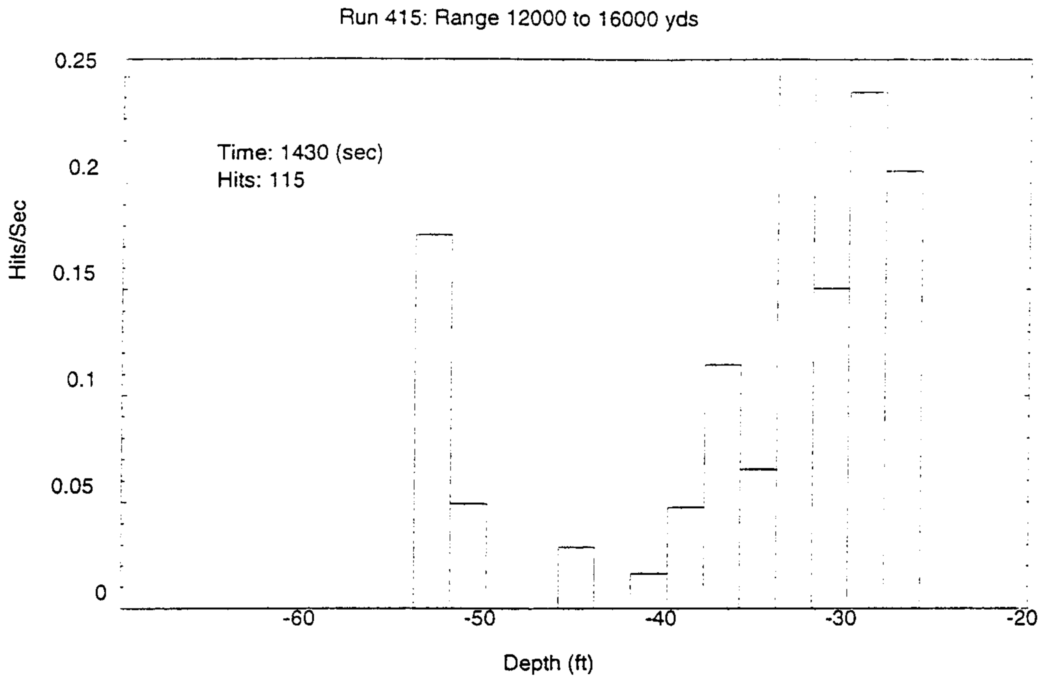


Figure A-12. Run 415, depth plots, exposure type – search mast at 11 ft.

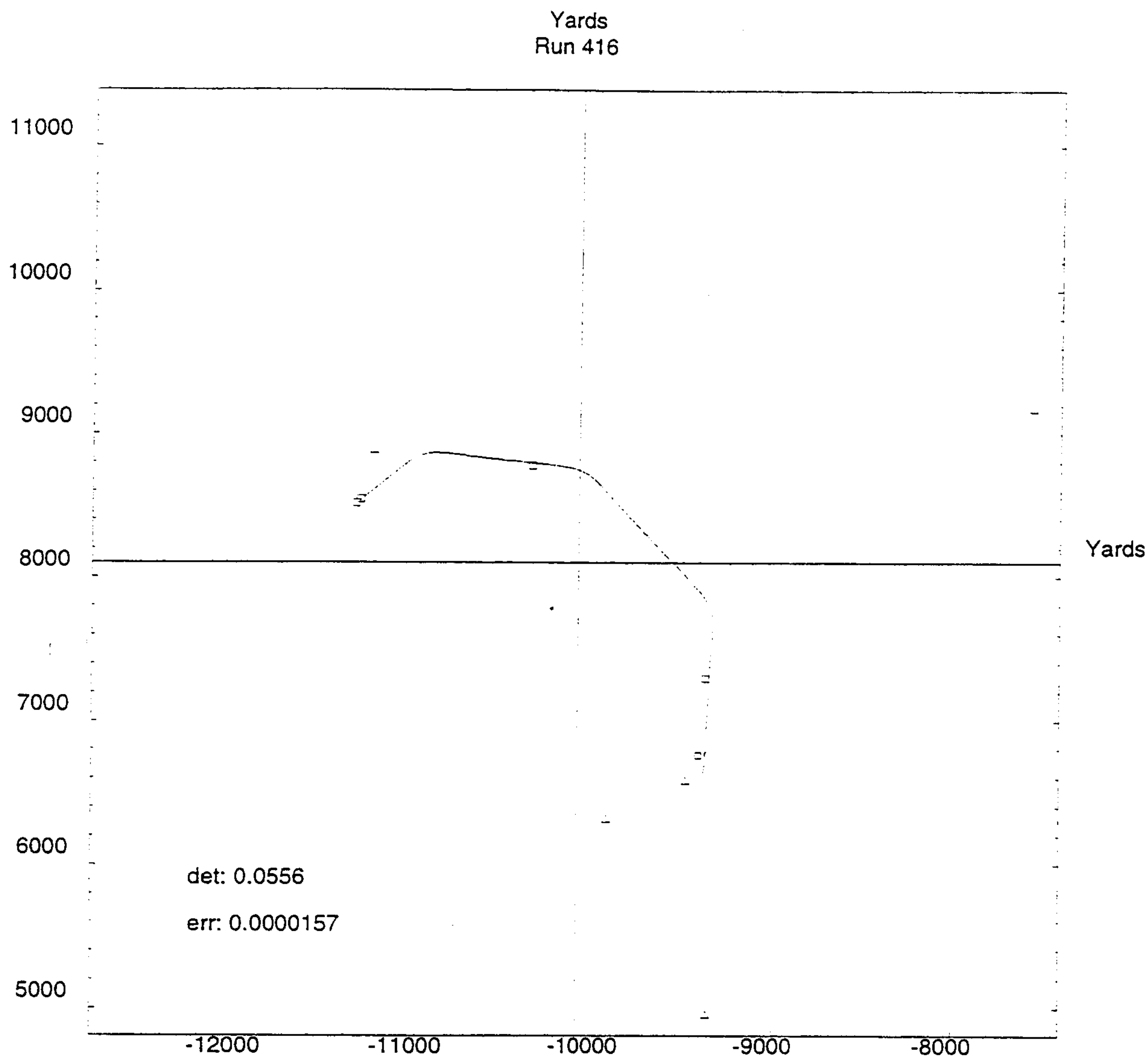


Figure A-13. Run 416, track plot type A, exposure type – search mast at 9 ft.

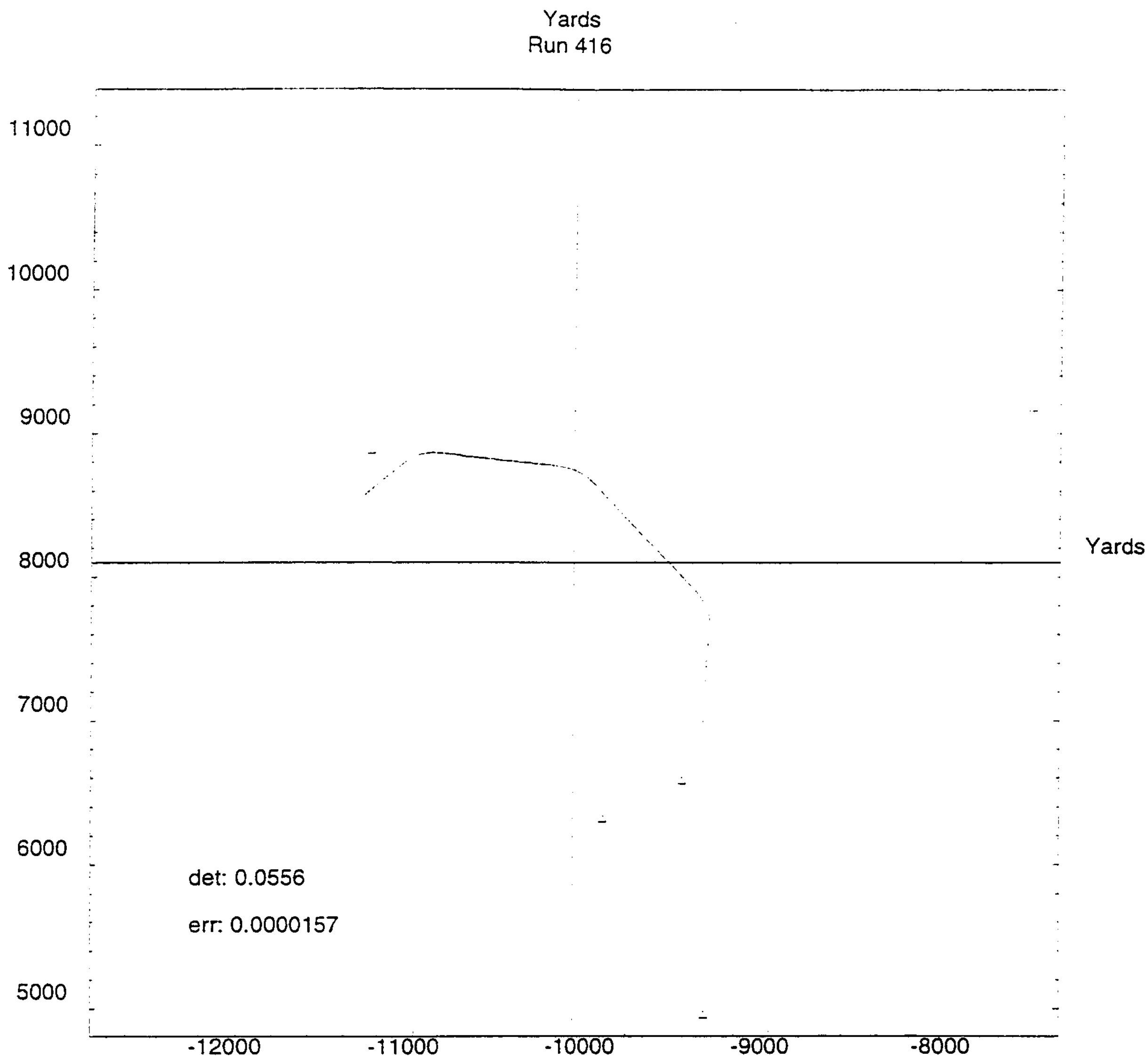
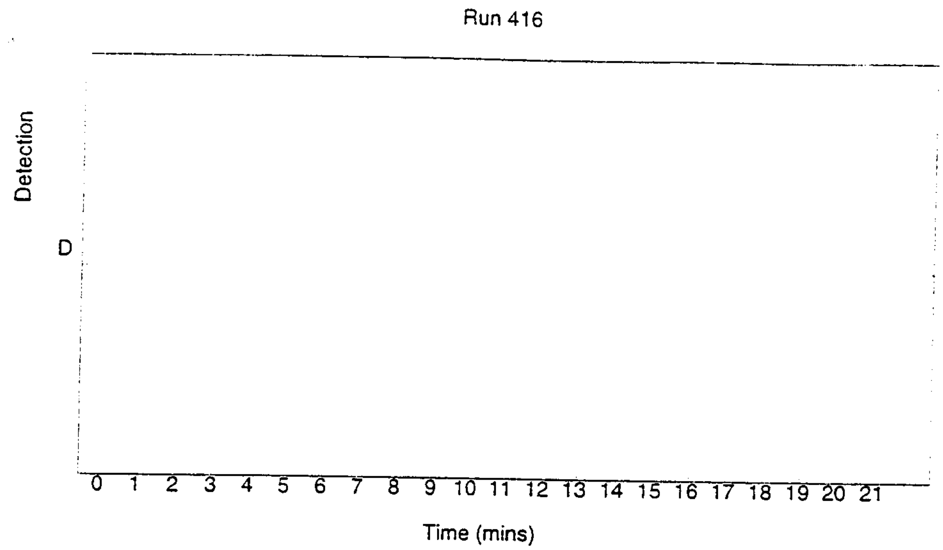


Figure A-14. Run 416, track plot type B, exposure type – search mast at 9 ft.



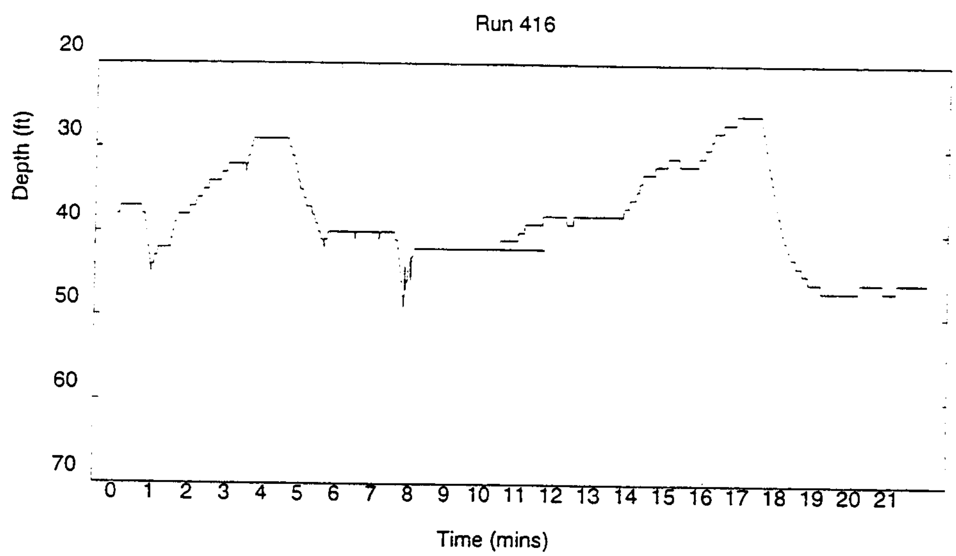
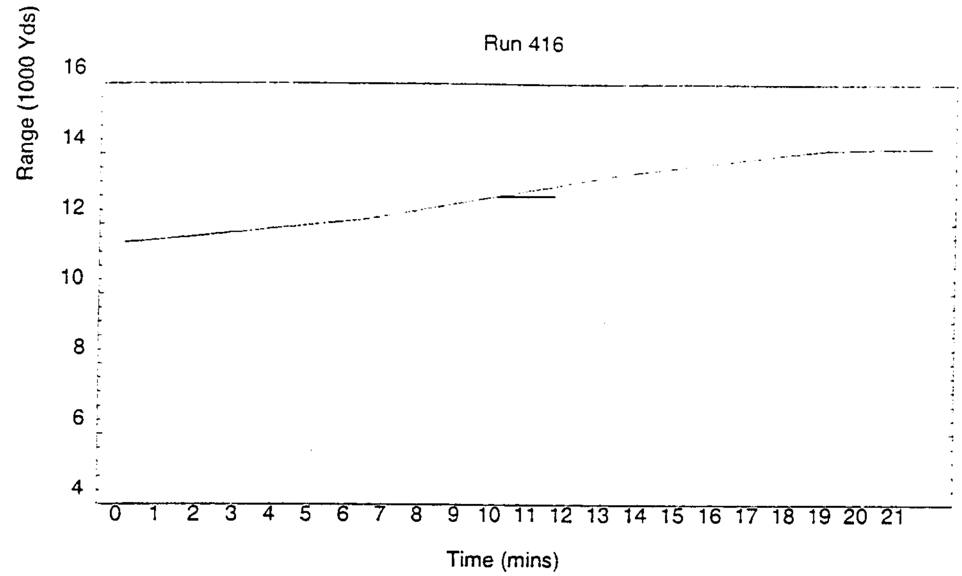


Figure A-14. Run 416, time plots, exposure type – search mast at 9 ft.



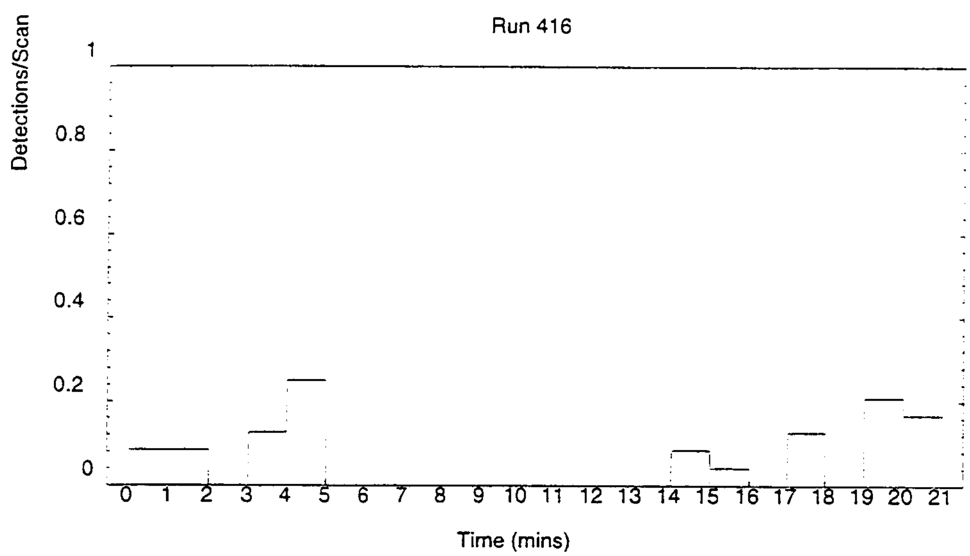


Figure A-14. Run 416, time plots, exposure type – search mast at 9 ft (Cont).

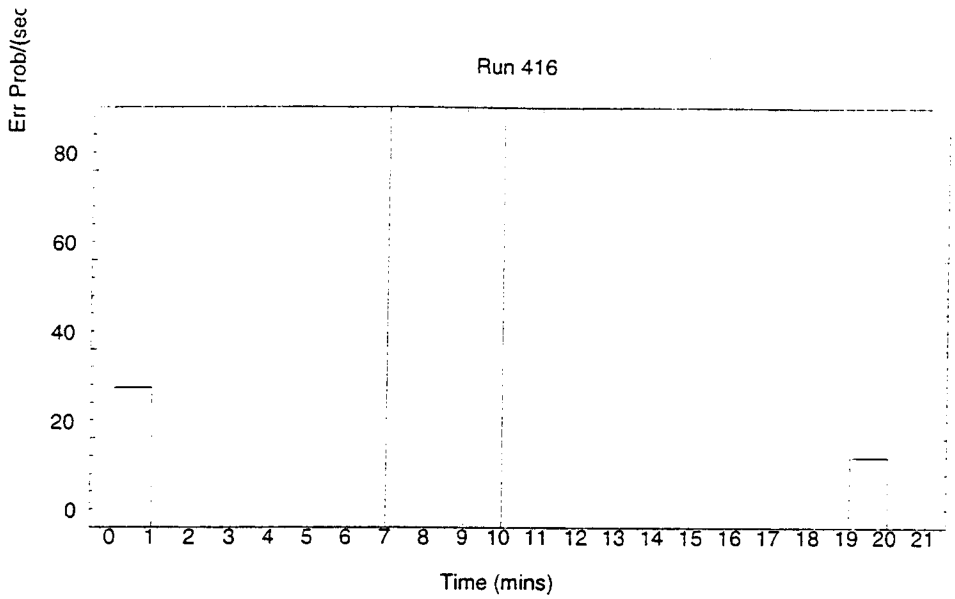
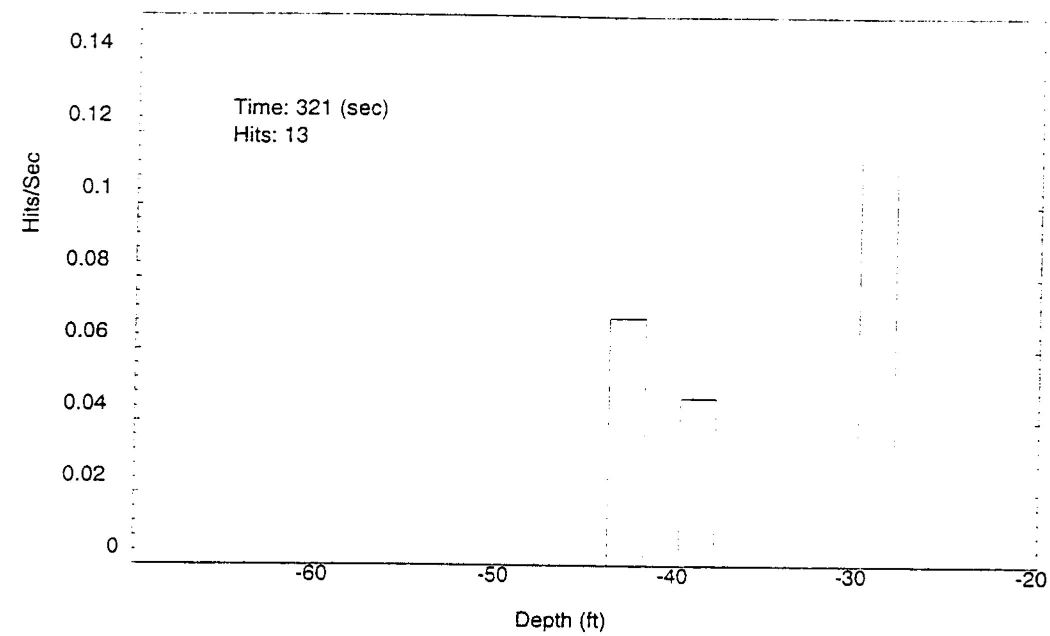


Figure A-14. Run 416, time plots, exposure type – search mast at 9 ft (Cont).

Run 416: Range 8000 to 12000 yds



Run 416: Range 12000 to 16000 yds

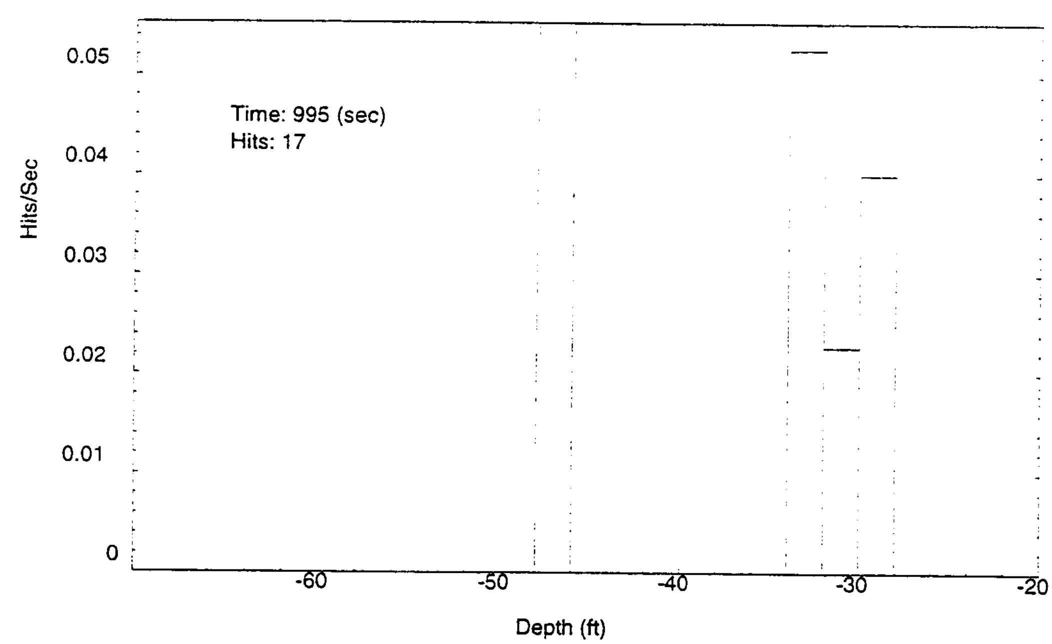


Figure A-15. Run 416, depth plots, exposure type – search mast at 9 ft.

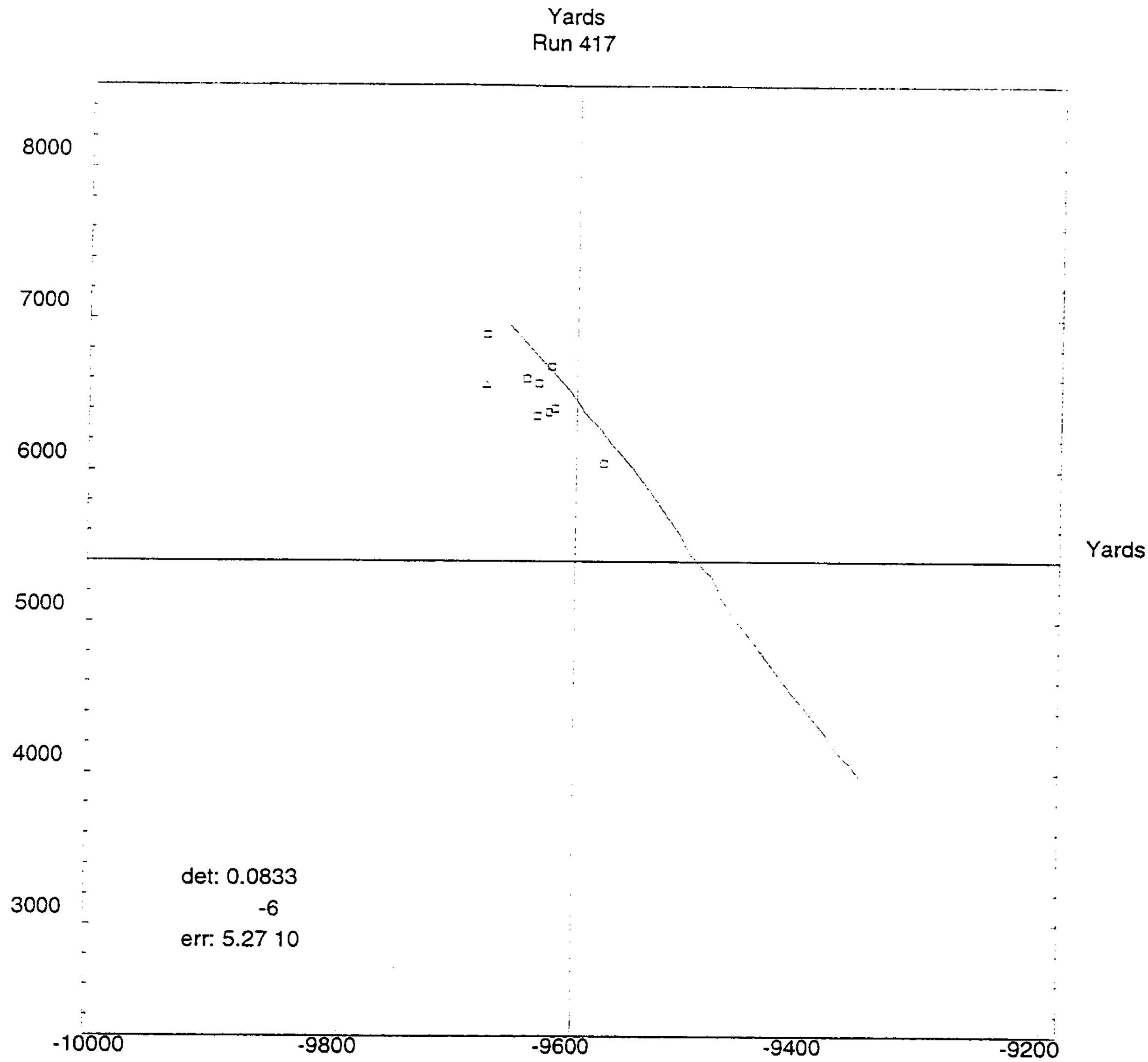


Figure A-16. Run 417, track plot type A, exposure type – search mast at 11 ft – 0 ft.

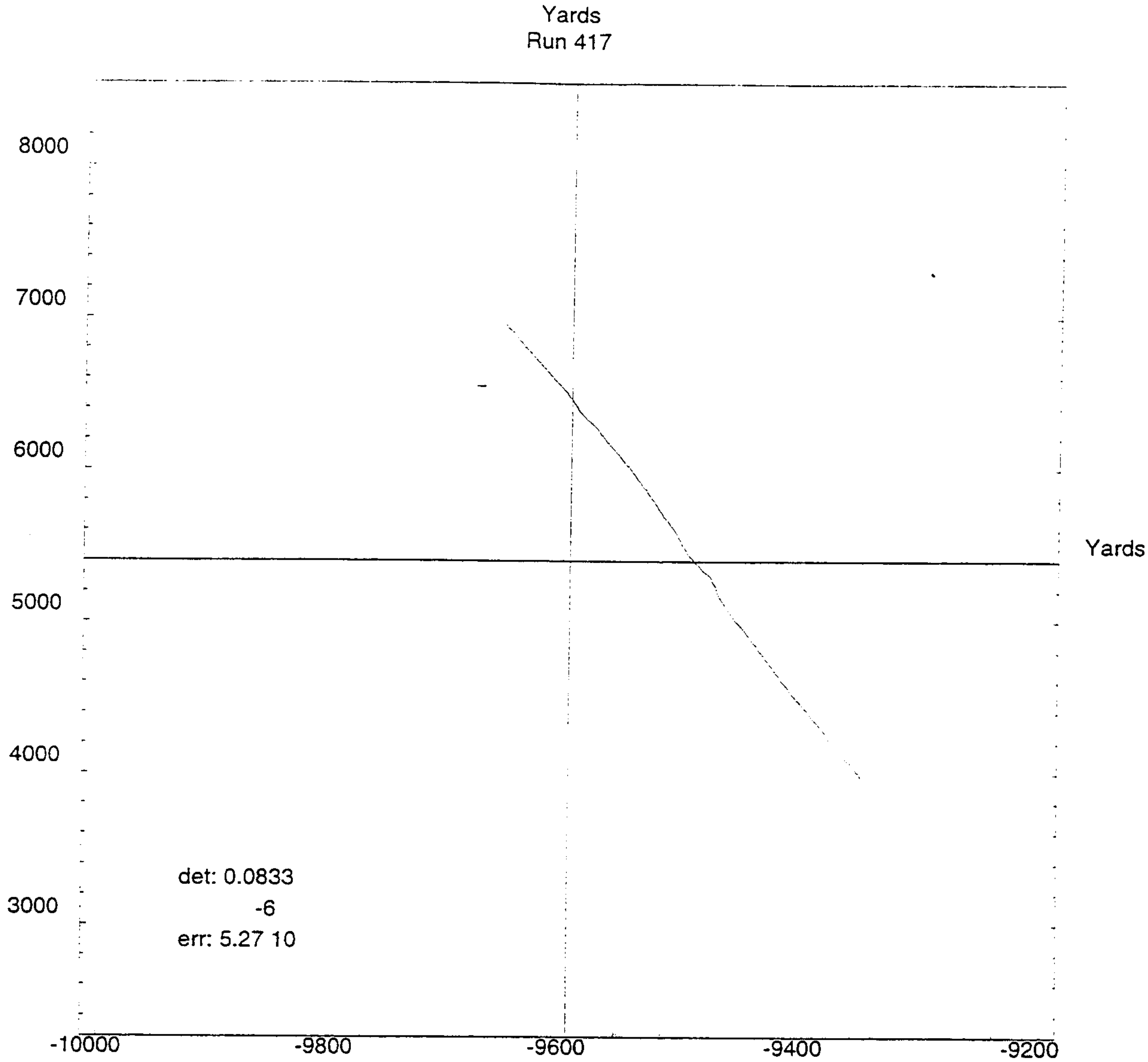
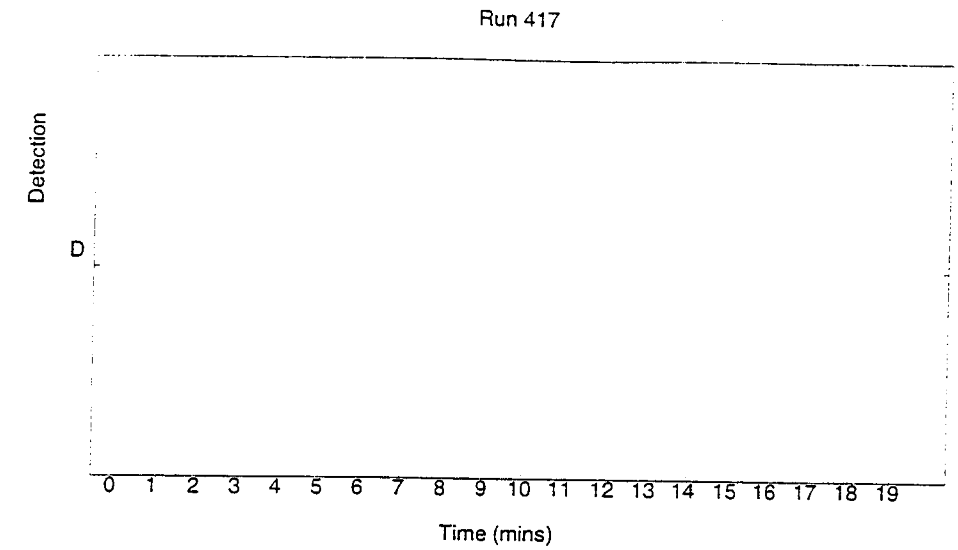


Figure A-17. Run 417, track plot type B, exposure type – search mast at 11 ft – 0 ft.



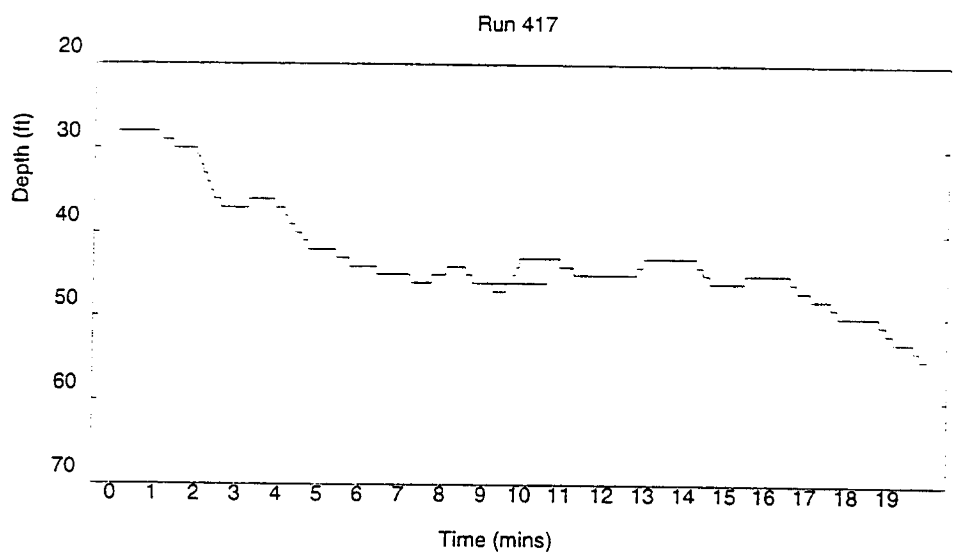
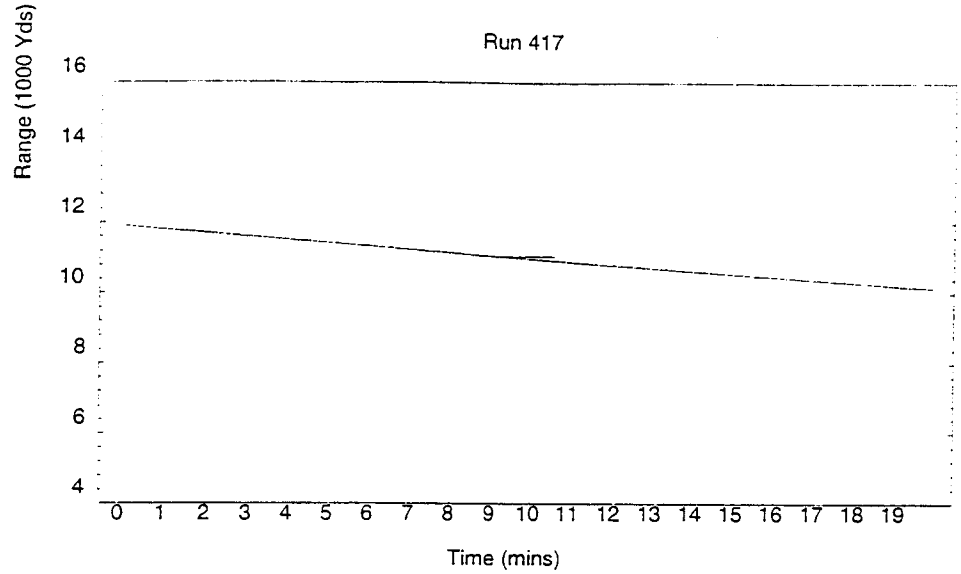


Figure A-18. Run 417, time plots, exposure type – search mast at 11 ft – 0 ft.



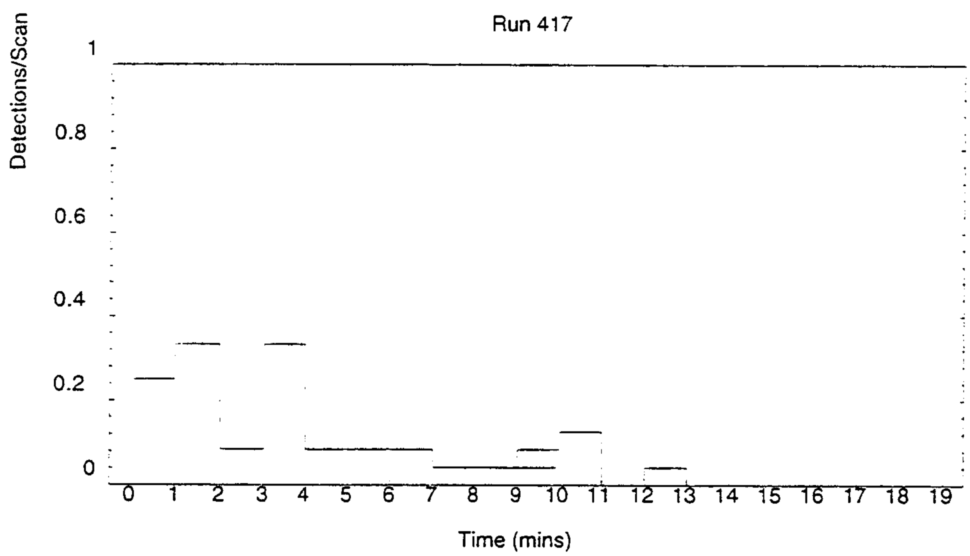


Figure A-18. Run 417, time plots, exposure type – search mast at 11 ft – 0 ft (Cont).

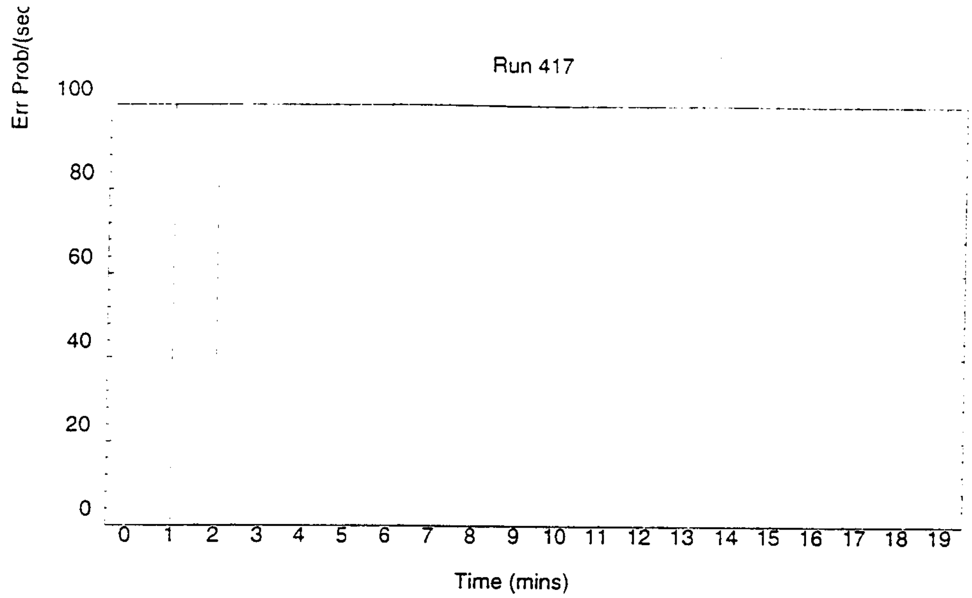


Figure A-18. Run 417, time plots, exposure type – search mast at 11 ft – 0 ft (Cont).

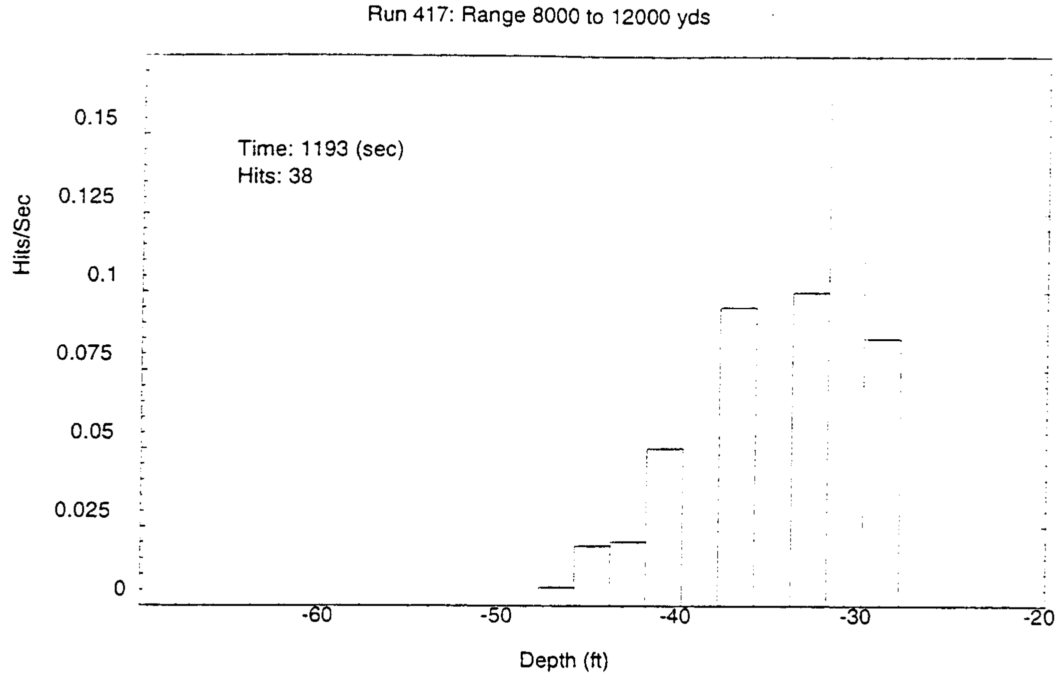


Figure A-19. Run 417, depth plots, exposure type – search mast at 11 ft – 0 ft.

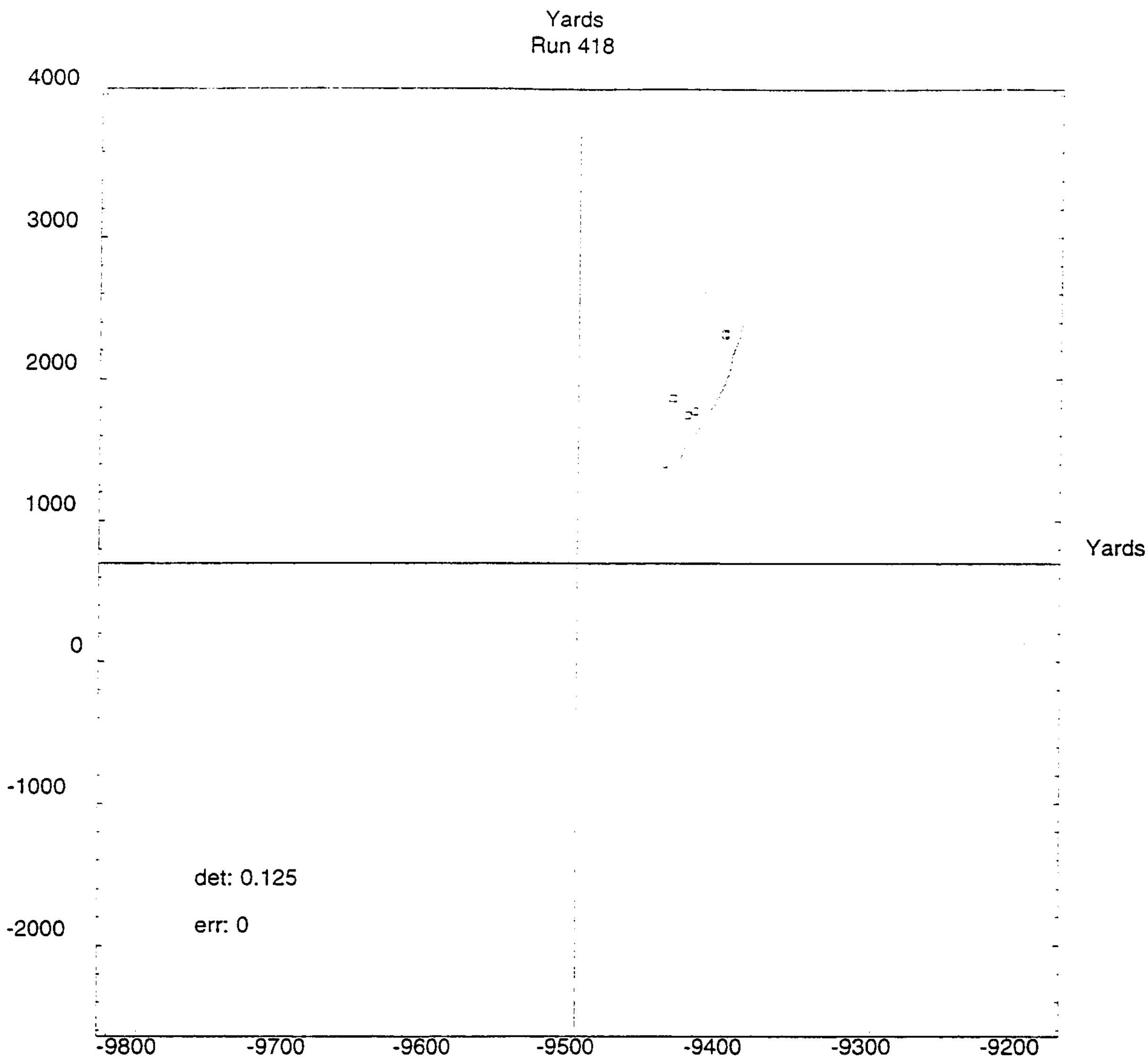


Figure A-20. Run 418, track plot type A, exposure type – search mast at 7 ft. transients.

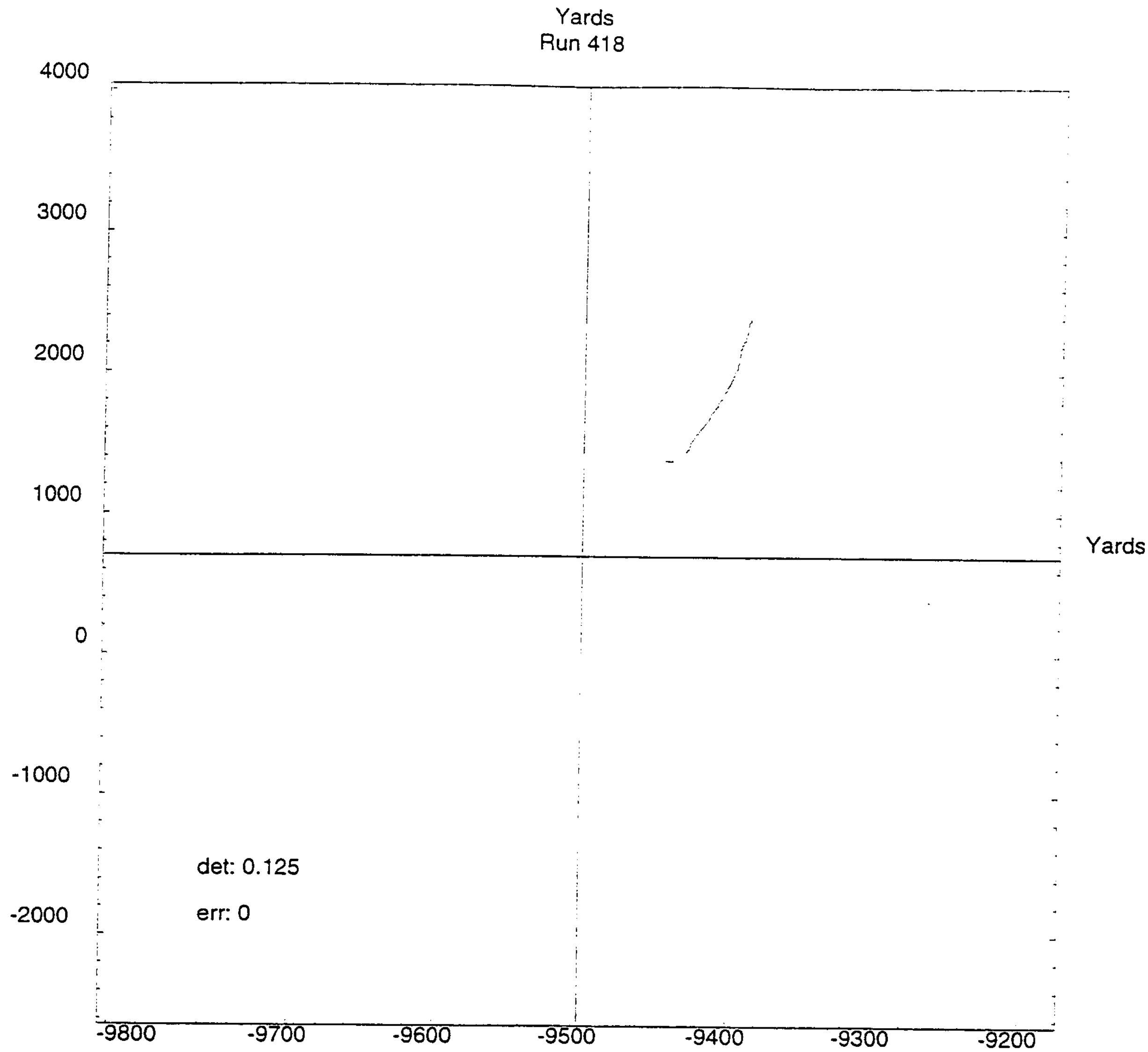
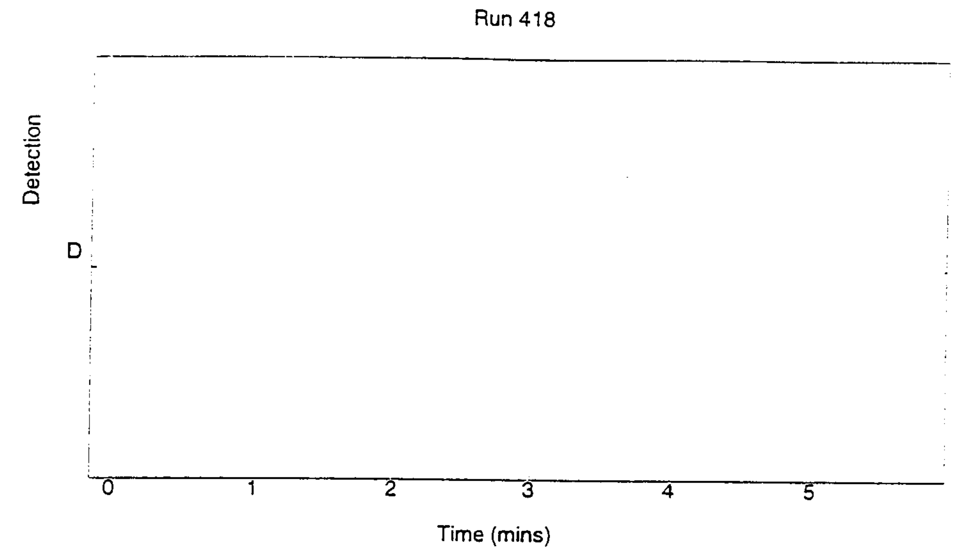


Figure A-21. Run 418, track plot type B, exposure type – search mast at 7 ft. transients.



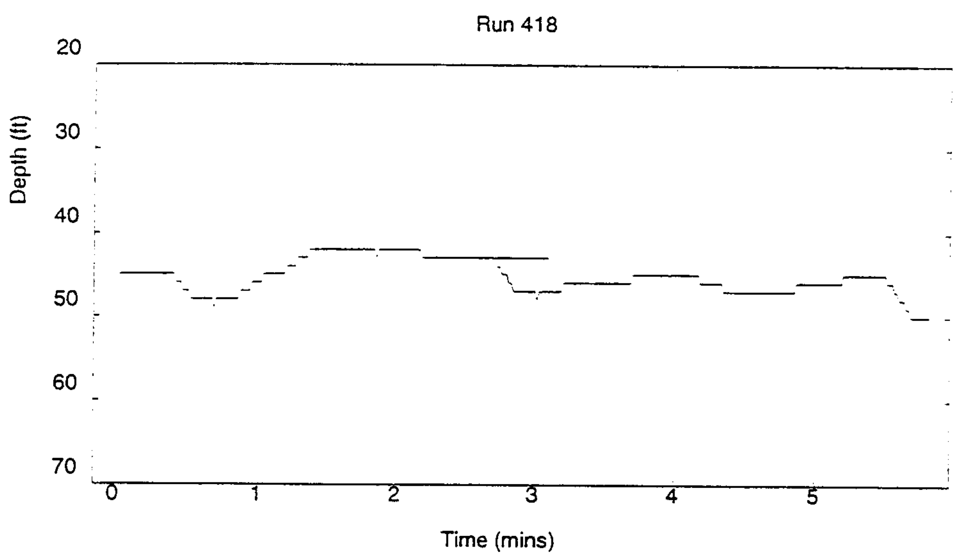
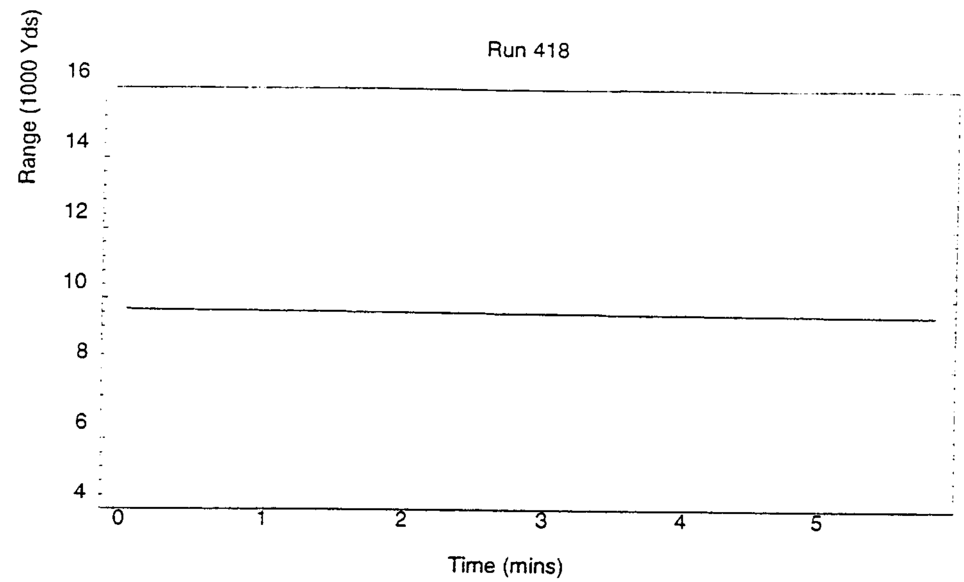


Figure A-22. Run 418, time plots, exposure type – search mast at 7 ft. transients.



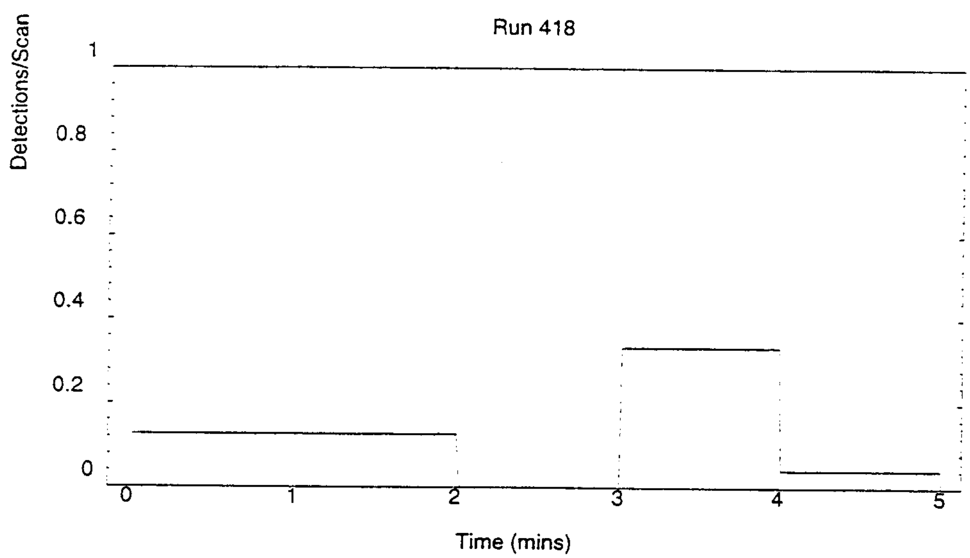


Figure A-22. Run 418, time plots, exposure type – search mast at 7 ft. transients (Cont).

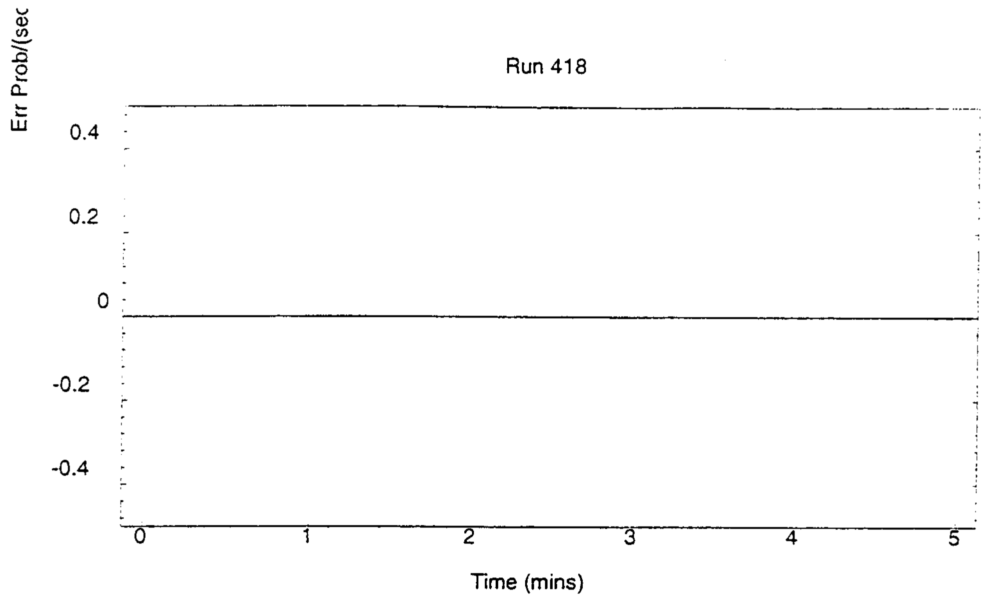


Figure A-22. Run 418, time plots, exposure type – search mast at 7 ft. transients (Cont).

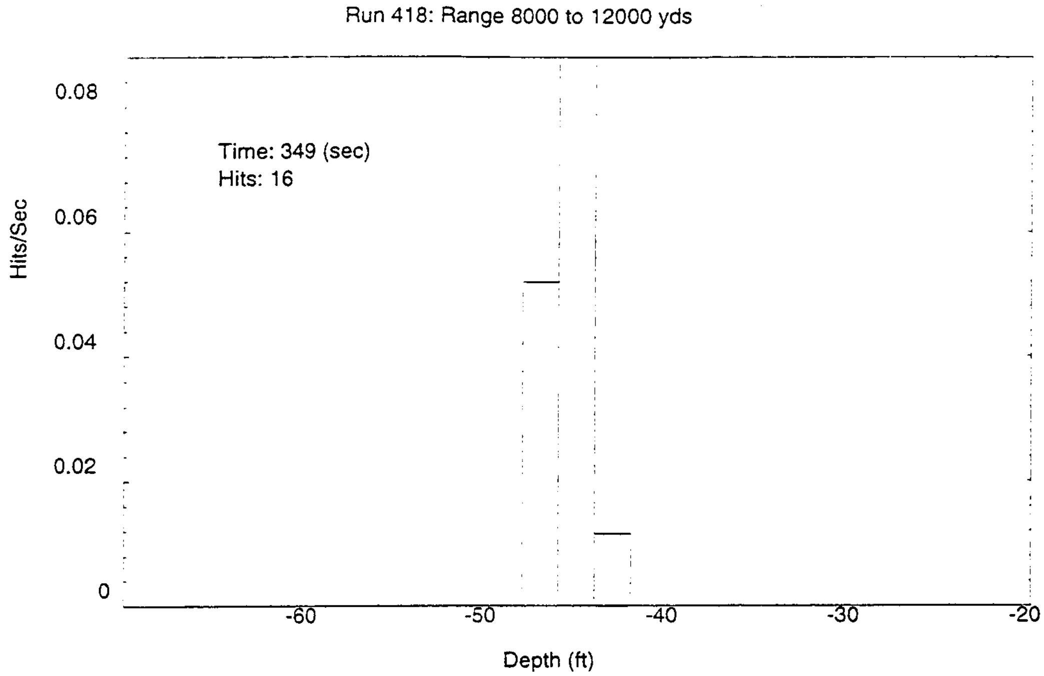


Figure A-23. Run 418, depth plots, exposure type – search mast at 7 ft. transients.

APPENDIX B
TACTICAL RUN TRACK PLOTS

The attached plots are derived from the recorded tactical runs conducted on 6 December 1994.

These plots are produced from screen dumps from the CEA-SCOPE software and show the SPLOTS as small circles. These SPLOTS are the result of clustered multiscan detections consistent with a mast exposure.

Two forms of screen dump are provided:

1. Plots of all SPLOTS accumulated over the period of the run
2. Plots of those SPLOTS associated with declared submarine tracks only.

Some of the plots have been timed to show the track and alert generated by the SPLOTS and representing a level 1 alert. The radar site is marked by a small circle with a coincident cross on the land to the right of the geographic displays. Small crosses indicating 1-nm markers are shown on the radial of 280 degrees.

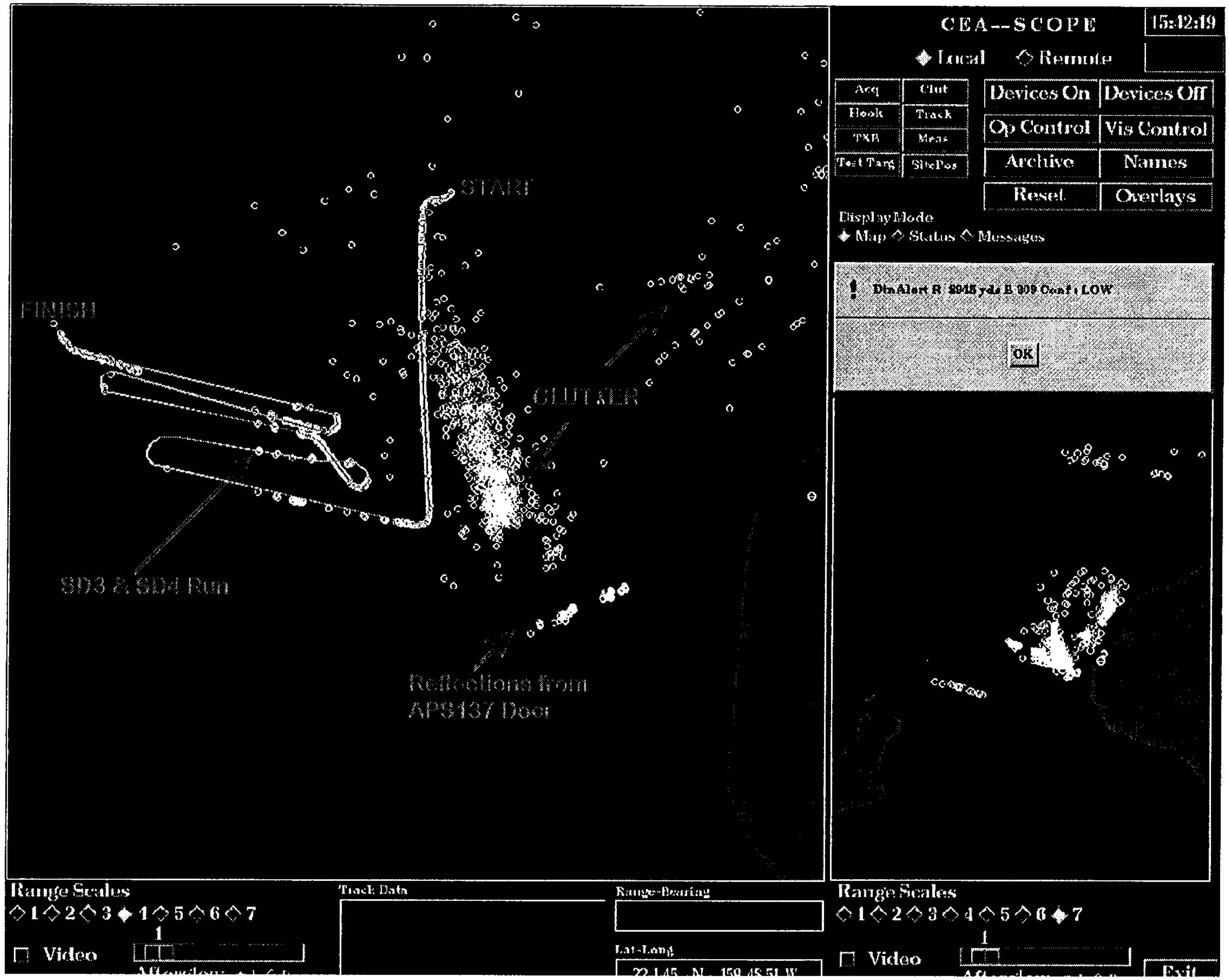


Figure B-1. SD1–Submarine track during the tactical runs.

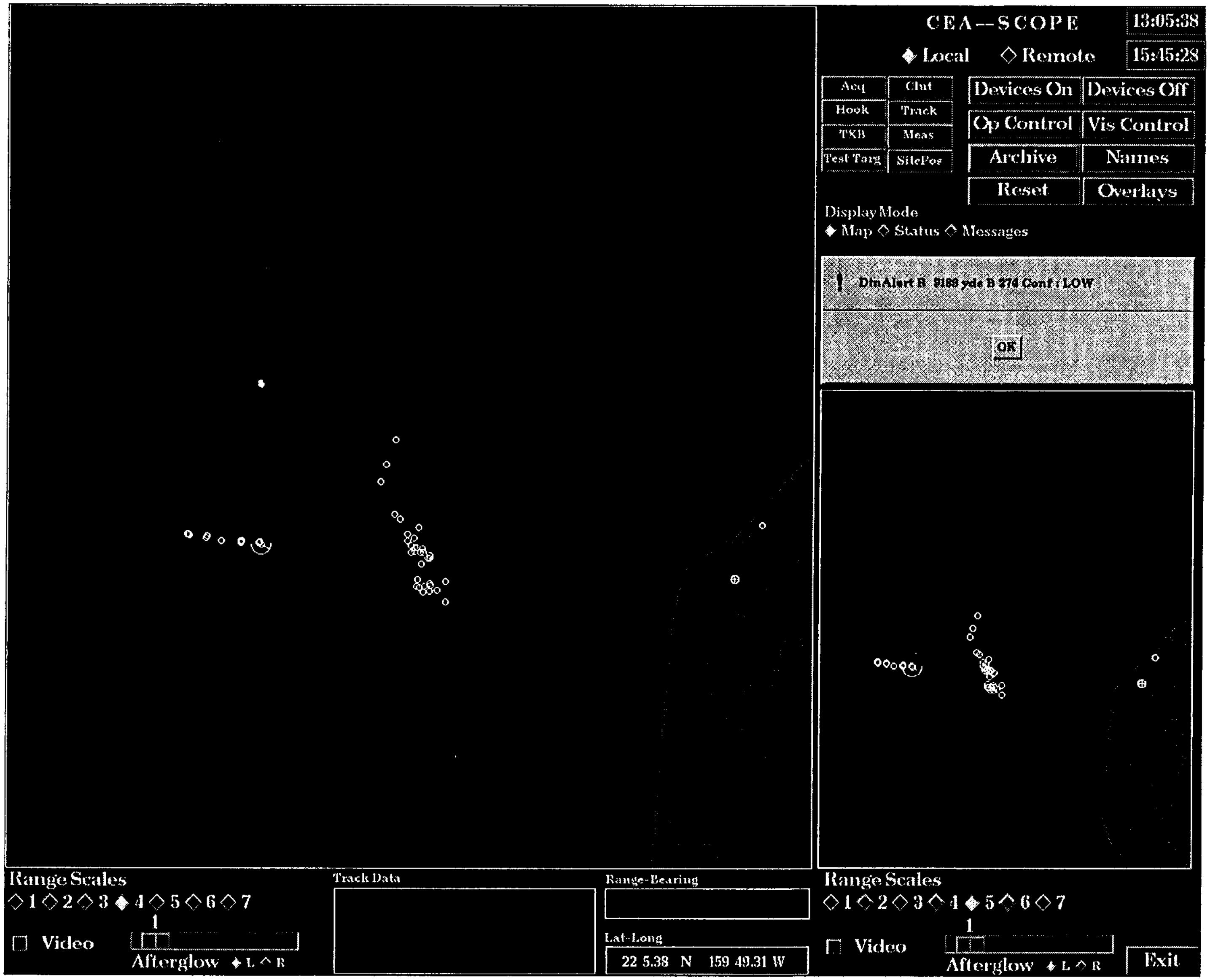


Figure B-2. SD2–Total SPLOT field over a period (20 min) of run SD3/4

Figure B-3. SD3–Tactical Run – SPLOTS associated with declared alerts.

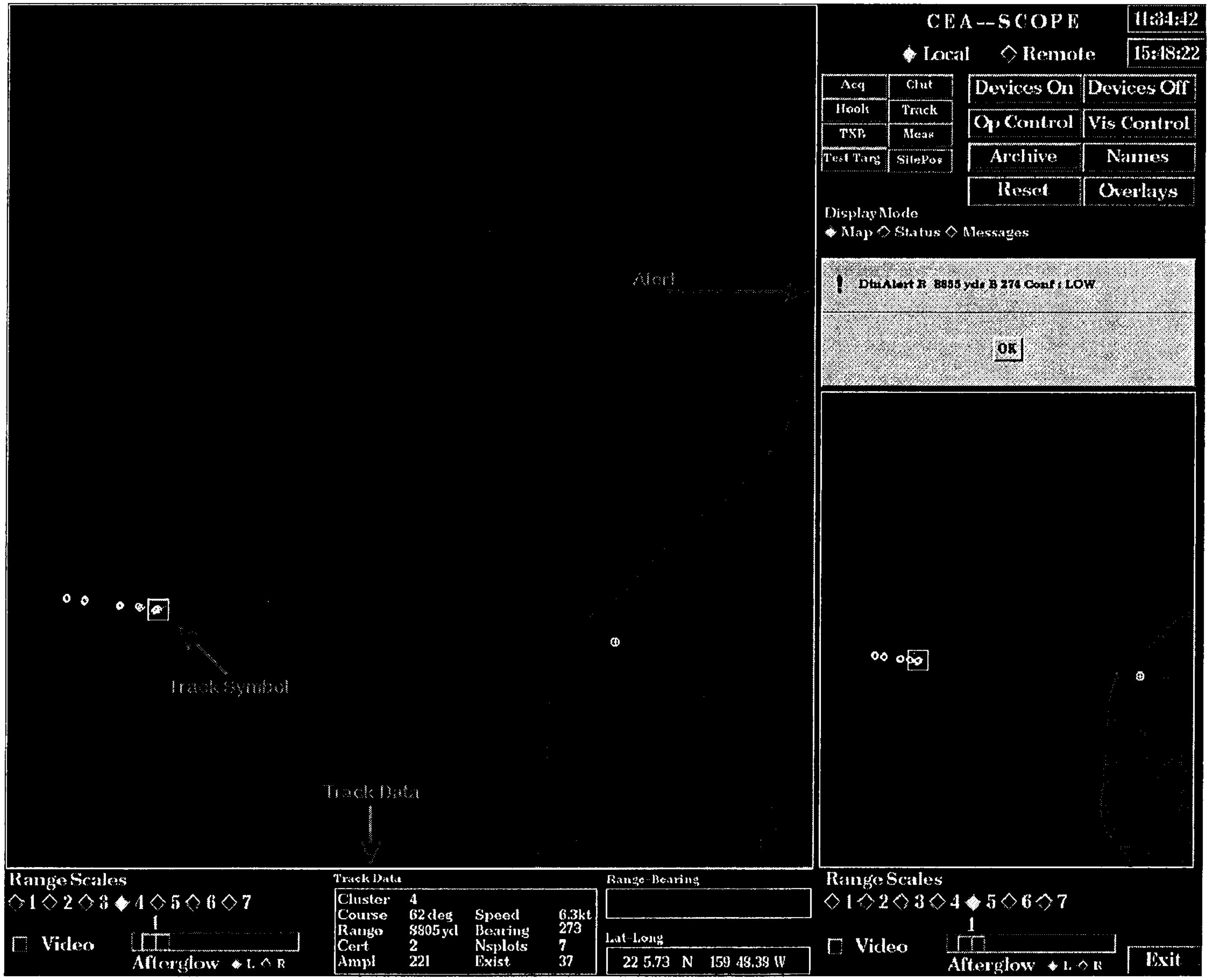


Figure B-4. SD4–Alert generaion.

APPENDIX C
TEST SYSTEM CALIBRATION AND MEASUREMENT ERROR REDUCTION

The error conditions which were likely to significantly effect the measurement process are summarized in the following paragraphs.

C.1 RADAR AZIMUTH ERROR

This error was caused by the inaccuracy of calibration of the antenna position readout to the True North Direction. This error is a one time calibration function that was performed on initial setup and remained throughout the trial. The magnitude of this error is likely to be of the order of several degrees as the method of calibration was crude in relation to the coarse map derived from Digital Chart of the World (DCW). CEA plans on using post-trial analysis to derive a correction factor for this error that can be applied retrospectively to the measured results.

C.2 RADAR SLANT RANGE ERROR

The radar slant range error was a product of the range of the target and the height above sea level of the antenna. This was caused by the difference between the direct slant range as measured by the radar and the ground range that was assumed to be the same. The magnitude of this error beyond ranges of 1000 yards is less than 0.6 yds, insignificant in terms of the system accuracy (approx. 7.5 yards rms.).

C.3 RADAR RANGE OFFSET ERROR

The radar range offset error was a result of the incorrect setup and calibration of the radar during the initial setup in which the fixed delay applied for the triggering offset of the radar was incorrect. This error could have been as much as several hundred yards but was likely to be less than 20 yards. CEA will calculate it in the post-trial data reduction process, and derive a correction factor to take account of it. This error was a fixed value for all range and azimuth positions.

C.4 RADAR RANGE CLOCK ERROR

The range clock error was a result of the incorrect frequency of the range measurement process in the radar system and produced an increasing error with increasing range. The value of this error component was likely to be less than 2 parts in 100,000, thereby less than 2 yards in 50 nm due to the radar clocking mechanism. A check was done to ensure that this component of error was not excessive during the analysis process.

C.5 RADAR SITE POSITION

The radar site position was provided as a latitude/longitude and should be geographically correct to within the survey and radar siting limits (less than 10 yards). The relationship of the site to the other objects reported by the range system should therefore be correct to this accuracy, plus the PMRF measurement accuracy.

C.6 MAP OVERLAY ERROR

The map used for the geographical overlay was derived from the DCW CD-ROM supplied by DMA. The absolute positions and the resolution of derived objects was relatively coarse and could not be relied on for accuracy better than several hundred yards. The overlay map did not effect the measurement accuracy of objects relative to the radar site or as supplied by the PMRF measurement system, as both the site and the objects reported by the PMRF system are in absolute latitude/longitude terms. The map was used for the "rough" initial setup of the radar calibration of range offset and azimuth by comparison of the radar image of the coastline and the map outline. It is CEA's contention that the coastline on the map is several hundred yards further out than the actual coastline. They will confirm this from chart and data analysis.

C.7 MAP PROJECTION ERROR

The map projection process was the key to being able to overlay and compare the position of the radar site and, hence, the targets that are measured relative to the radar site and the data supplied from the PMRF measurement system. The map projection used in the Mast Detection System (CEA-SCOPE) is gnomonic, with the projection point at approximately 30 nm from the radar site. Although this is not ideal, the projection errors are relatively small and have not been removed from the data set.

C.8 RADAR TRACKER ERROR

The errors introduced by the radar track processor were a result of the quantisation and measurement processes. The radar track processor was previously qualified to accuracies of 7.5 yards rms in range and 0.15 degrees in azimuth. These values were assumed as the starting point for the analysis process.

C.9 SYSTEM TIMING ERRORS

The time reference between the PMRF and CEA-SCOPE systems could introduce a velocity-dependent error to the positional comparison process. This error amounts to less than 2.8 yards for each second of time difference. The CEA-SCOPE system was adjusted to within 1 sec of the range time and, hence, the magnitude of this error should be less significant than the radar system measurement errors.

C.10 PMRF BARSTUR UNDERWATER RANGE MEASUREMENT ACCURACY

The measurement accuracy of the BARSTUR range is quoted as 6 to 10 ft in the "PMRF RANGE USER'S HANDBOOK". A value of 3 yards will be used as a convenient single number for the purposes of this report. This is approximately half the accuracy expected of the radar measurement system in range and 1/14 of the error expected in azimuth at ranges of 6 nm. The PMRF system is, therefore, taken as the initial reference based on significance of error.

C.11 ERROR DETERMINATION AND CORRECTION STRATEGY

The significant errors relevant to this trial were judged to be the radar azimuth and range offset (Az_e,R_e). These errors dominate all other error sources and so all radar system errors will be initially resolved to these two values. The process to determine these values involved the comparison on a time basis of the position as measured on the PMRF and by the radar system of multiple data points. The difference was then resolved into the significant error components. These error components are then used to convert the PMRF range data values into the same co-ordinate space as the radar system using the process shown in figure C-1.

The reason for conversion into the radar system of coordinates was to allow the input of the range-based data into the display and replay processing system of the CEA-SCOPE to make further analysis and replay convenient. This conversion process was intended to initially use only two fixed values of data:

1. The radar position relative to the PMRF datum in Cartesian coordinates. These coordinates were derived from the surveyed positions of the range datum and the radar site and were accurate to ±2 yards.
2. The radar azimuth and range offset values derived by the above analysis.

The relationship of these data elements is illustrated in figure C-2.

After initial analysis, a further two values were introduced due to an apparent Cartesian error in the range datum. These values are the X offset and Y offset values for the range datum.

C.12 DERIVED RADAR AZIMUTH AND RANGE ERRORS

The derived values of radar azimuth and range offset errors as a result of the initial analysis using the range and radar observed values was as follows:

Range offset: –355 yards

Range standard deviation: 43 yards

Azimuth offset: –0.87 degrees

Azimuth standard deviation: 0.37 degrees

The wide standard deviation of these errors and the cyclic nature of the range error indicated a systematic error in the x,y positioning of the radar site with respect to the range datum or in the range measurement system relative to the surveyed radar position and range datum. This error was analyzed and resulted in the following x and y systematic errors. Applying these errors to correct the range values, and again running the radar results against the range values, produced a considerably better standard deviation and bias for the radar errors.

Range offset: 1.5 yards

Range standard deviation: 29 yards

Azimuth offset: 0.0 degrees

Azimuth standard deviation: 0.2 degrees

The following conclusions have been validated by the analysis:

1. The X,Y values of target position and the latitude and longitude readouts are consistent with the use of the CENTER OF BARSTUR DATUM to within 5 yards. (Method: calculation using 3-D geometry)
2. The surveyed position of the LAPA datum (radar site) should be accurate to within 2 yards. (Method: Surveyed data available from PMRF)

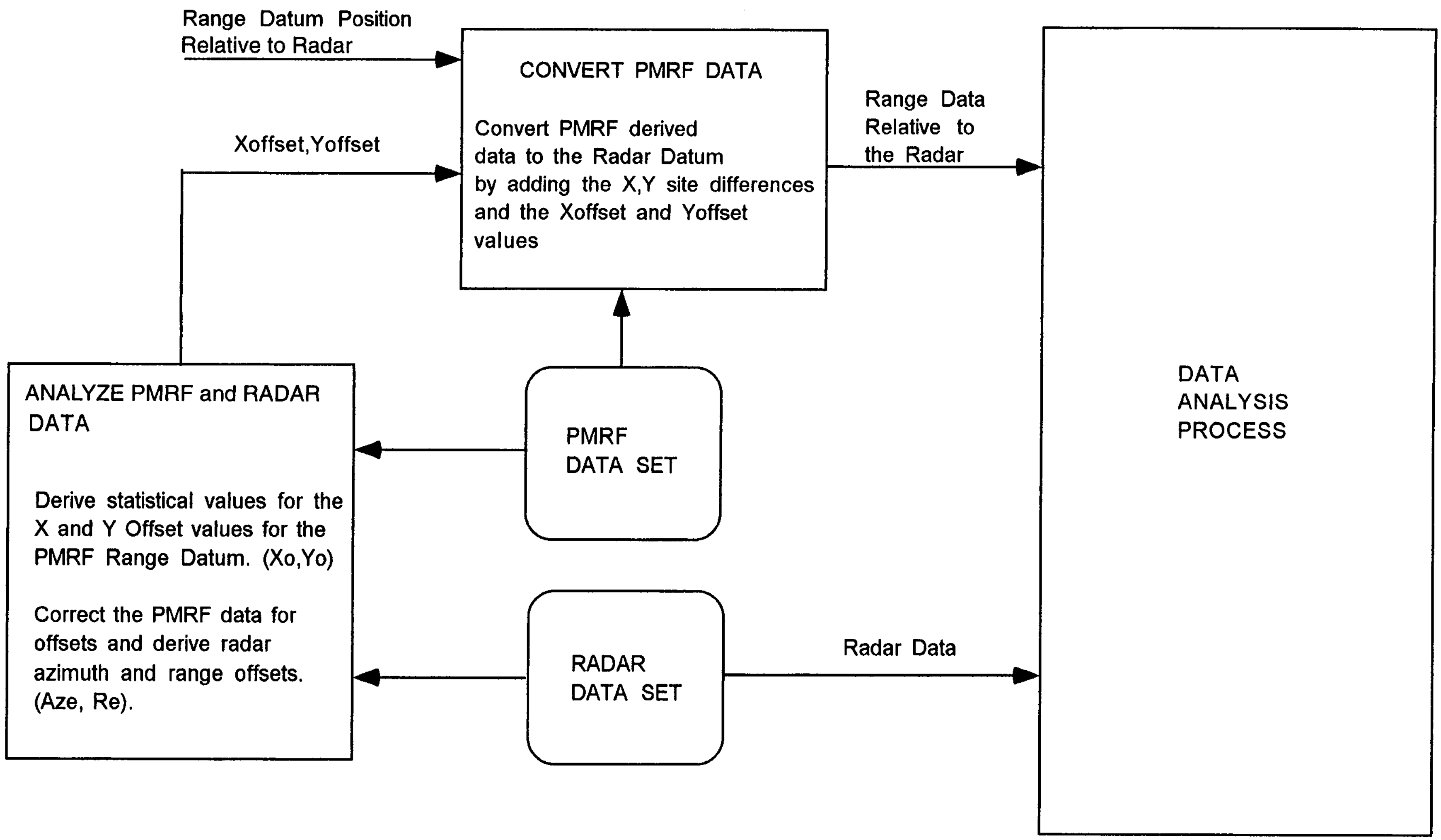
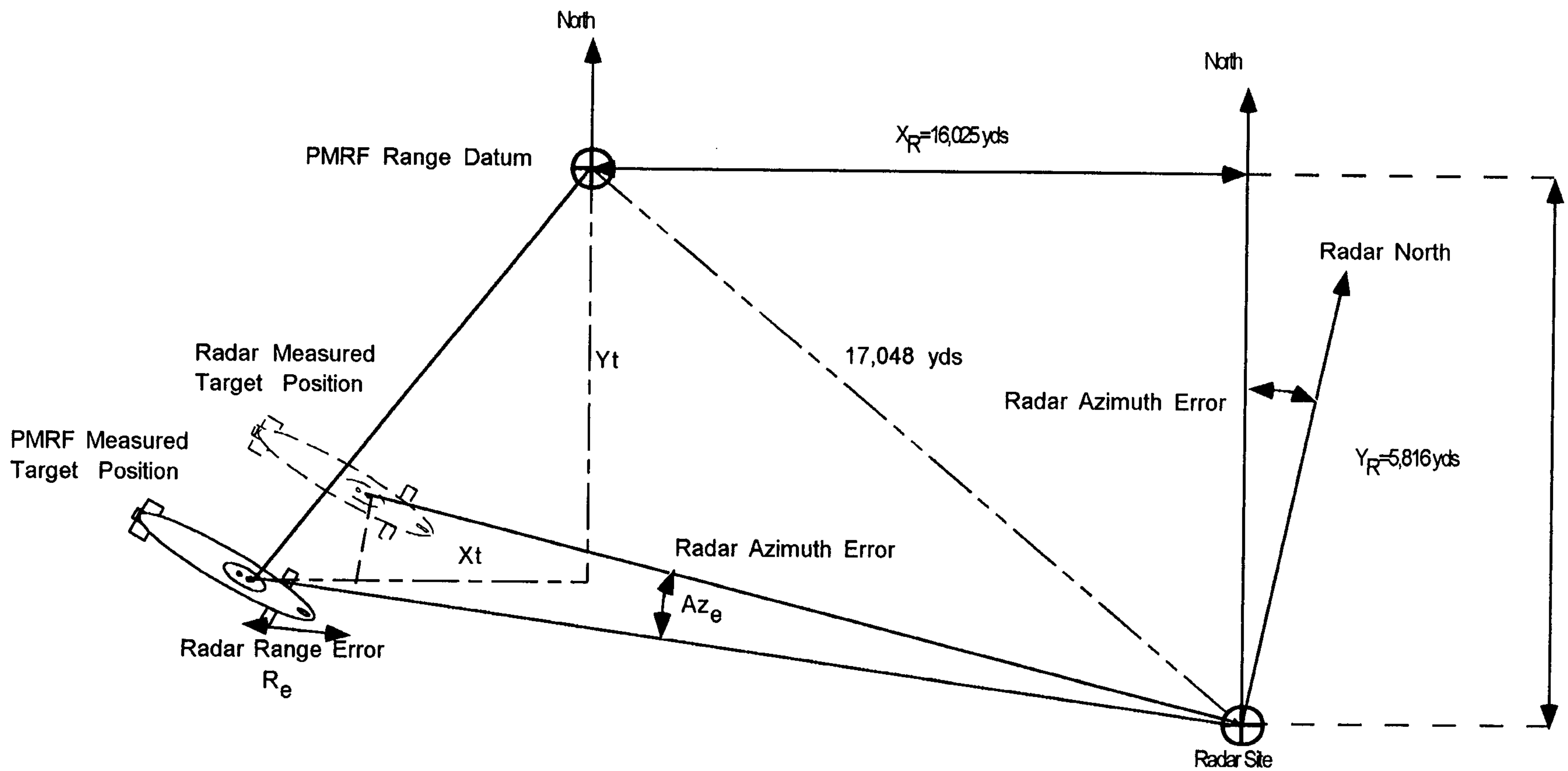


Figure C-1. Conversion of PMRF range data to the radar datum.



	Latitude	Longitude
PMRF Range Datum (Center of BASTUR System)	N22 7' 9.9811" (22.1194392)	W 159 55' 10.1957" (159.9194988)
Radar Site (LAPA)	N 22 4' 17.0686" (22.07140794)	W 159 46' 38.4528" (159.7773480)

DoD World Geodetic System (WGS 84)

Range and Bearing of Radar Site from the PMRF Range Datum - Range = 17,048 yds, Bearing = 109.95 degrees

Figure C-2. Conversion of PMRF data to radar datum.

3. The resolved radar range and azimuth data compared to the range measured position of the target over all runs shows a large non-polar variance that cannot be explained by the radar measurement system. (Method: Manual and statistical analysis of radar data compared with PMRF data).
4. Resolving the measurements into four error components (range, azimuth, x, and y errors) provides a significant reduction in the variance of the assessed errors, consistent over all runs analyzed. This indicates a datum error as well as a radar range and azimuth error. (Method: Analysis)
5. The datum error in x and y is 326 yards in y and 228 yards in x. The error is such that the radar actual position appears to the southeast of the surveyed position, or alternatively, the actual CENTER OF BARSTUR DATUM appears to be to the northwest of the surveyed position.
6. Removing these bias values from the range data produces a range offset of 1.5 yards and azimuth error of 0.0 degrees with respective standard deviations of 29 yards and 0.2 degrees. (Method: Analysis of radar data compared to PMRF data)
7. The source of error has subsequently been isolated to the use of the radar position in "Old Hawaiian" coordinates and subsequent analysis takes this into account.

APPENDIX D
LIST OF ACRONYMS

amsl	Above Mean Sea Level
APS137	Helicopter Radar System for Detecting Submarines
CEA	CEA Technologies PTY Limited, Canberra Australia
CFAR	Constant False Alarm Rate
COTS	Commercial-Off-the-Shelf
dBsqm	Decibles per square meter
GDFS	Graphic Data Fusion Software
MIRSS	Mobile Inshore Radar Surveillance System
MIUW–SU	Mobile Inshore Underwater Warfare–System Upgrade
NSAP	Naval Science Assistance Program
Pd	Probability of detection
PMRF	Pacific Missile Range Facility
PRF	Pulse Repetition Frequency
RCS	Radar Cross Section
SPLOTS	Special Plots from the CEA MIRSS Tracker
sqm	Square meter
TRB	Torpedo Recovery Boat

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13. ABSTRACT *(Maximum 200 words)*

The Surface Ship Periscope Detection Radar (SSPDR) project was initiated to determine if a commercial off-the-shelf (COTS) radar track processor system could meet the requirements of the Navy's mission needs statement for periscope detection capability. A COTS system built by CEA Ltd. of Australia was identified as a candidate for test and evaluation. The purpose of the first test was to determine the capability of the CEA radar track processor to detect submarines operating at periscope depth as currently configured for use in the Navy's Mobile Inshore Underwater Warfare–System Upgrade (MIUW–SU) Program. The system demonstrated an excellent capability in the detection of periscopes to the theoretical limits of the installation. This report discusses the results of this test.

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